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EFFECT OF INTEGRATED APPLICATION OF SOIL AMENDMENTS ON NUTRIENT UPTAKE AND SOIL PROPERTIES IN A TROPICAL ALFISOL

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ABSTRACT

A field experiment was conducted on a tropical alfisol for two consecutive years to determine the effect of integrated application of nutrient sources on nutrient uptake and soil properties. The treatments consisted of two rates of poultry manure (0 and 5 t ha^{-1}), three rates of N fertilizer (0, 50 and 100 kg N ha^{-1} applied as urea), three rates of P fertilizer (0, 30 and 60 kg P ha^{-1} applied as single superphosphate) and two soybean treatments (with or without legume residue) arranged as a factorial experiment using Randomized Complete Block Design (RCBD) with three replicates. Soil samples were collected, processed and analyzed for soil nutrients and properties before planting and after harvests. Results showed that combined application of manure and N fertilizer had greater impact on soil organic matter build up than the separate inputs when singly applied. Results also revealed manure and N fertilizer to be the major factors that controlled plant uptake of N throughout the study. Legume, throughout the experiment was not found to be an important factor in plant uptake of N and P. CEC values were observed to be generally slightly higher in the second year of the experiments indicating a positive effect of integrated application of the soil amendments on soil properties.

INTRODUCTION

Low activity clays have been observed to increase in proportion with increasing proximity to the equator. This explains the preponderance of low activity clays in tropical regions and the attendant low CEC of the soils in this region. The soils of this region are therefore, expectedly, inherently low in nutrient status or fertility which however, is naturally made up for by the rapid formation and accumulation of organic matter which is very high in CEC. Unfortunately, the organic matter, which is considered to be the life wire of tropical soils is either removed in the course of inevitable mechanical land clearing or rapidly depleted as a result of continuous cultivation leaving the farmers with no option than to look for ways of improving the fertility of the soil by way of addition of soil amendments.

Against the background of degrading agricultural soils and declining soil fertility, a soil fertility initiative was launched by a consortium of seven international organizations for sub-Saharan Africa following the World Food Summit of 1996. The increased use of fertilizers to ameliorate soil fertility problem is often questioned on account of possible negative effect on the environment. In some industrialized countries,

pollution or eutrophication of ground water has been linked to excessive or improper application of fertilizers. In developing countries however, especially in the sub-Saharan Africa, environmental problems, noted Dudal (2002) and Adetunji (2004), are not related to overdose or overuse of fertilizers but rather to a deficiency of plant nutrient which leads to the depletion of soil fertility and hence production potential. As soil fertility declines, noted Adetunji (2004), soil structure weakens and the soil becomes susceptible to erosion.

Fertilizer use in Nigeria is very low when compared with requirements of crops. In Nigerian Savanna zone for example, where soil organic matter is very low, fertilizer recommendation of 100-200 kg N ha^{-1}; 40-50 kg P_20_5 ha^{-1} and 30-45 kg K_20 ha^{-1} is required for good yield of maize. The recommendation above gives an average nutrient requirement of 170-215 kg ha^{-1}. A recent publication by FAO (1999a), however, gives the average fertilizer consumption in Nigeria to be 4.5 kg ha^{-1} as against world average of 90 kg ha^{-1}, 29.0 kg ha^{-1} for Kenya and 262 kg ha^{-1} for China. These figures are an indication that fertilizer use in Nigeria is still on a very low level and really, among the lowest in the world.

The soil fertility initiative is intended to support the enhancement of soil productivity in a very broad manner. It is therefore, beyond fertilizer application, seeks a shift in focus from the soil nutrient status to a combination of improved seed, appropriate tillage practices, crop rotations, water management, soil conservation measures, strategic use of organic matter and the judicious use of inorganic fertilizers (Dudal, 2002).

There is nothing really wrong with mineral fertilizers when properly used. The plant does not care whether the nitrate or phosphate ion it assimilates comes from a bag of fertilizer or from a decomposing leaf. The soil micro-organisms however do care because mineral fertilizers do not provide carbon while organic inputs do. This singular fact necessitated the need for combined application of mineral and organic inputs for sustainable agricultural production. From the 1980s, FAO, in recognition of this fact promoted the introduction of integrated plant nutrient system (IPNS) that makes maximum use of local sources of plant nutrients of both organic and inorganic origin (Dudal and Roy, 1995). The general belief is that by using various combinations of legume rotations, green manures and other locally available resources plus adequate and affordable amounts of fertilizers, it is possible over time, to improve soil fertility and thereby increase the yield potential of soils in Africa. While fertilizers supply plant nutrient, soil organic matter maintains the physical and physico-chemical components that contribute to soil fertility such as cation exchange capacity (CEC) and soil structure (Vanlauwe *et al.*, 2001).

This paper reports an experiment conducted in 2004 and 2005 to evaluate the effect of integrated application of nutrient elements on nutrient uptake and soil properties in a tropical Alfisol.

MATERIALS AND METHODS

Surface soil samples (2-20cm) were taken from the experimental site at the University of Agriculture in Abeokuta, South Western Nigeria. The site had not received fertilizer for five years prior to the experiment. The project site was located on the upper slope of a highly weathered sedentary soil (Iwo series). The soil is sandy loam in texture and classified as Kandic Paleustalf (Aiboni, 2001). The soil samples were air dried, sieved through a 2mm sieve and analyzed for selected physical and chemical properties.

Particle size distribution was determined by the hydrometer method (Udo and Ogunwale, 1986) using sodium hexameta-phosphate as the dispersing agent. Soil pH was determined potentiometrically in distilled water at soil to water ratio 1:1. Exchangeable bases (K, Na,

Ca and Mg) were extracted with neutral normal NH_4OA_c. Potassium and Na in the extract were determined by flame photometry while Ca and Mg were read by atomic absorption spectrophotometer. Exchangeable acidity was determined by titration of normal KCl extract against 0.05 sodium hydroxide to a pink end point using phenolphthalein as indicator (Mclean, 1967). Effective cation exchange capacity (ECEC) was obtained by summation of exchangeable bases and exchangeable acidity. Available P was determined by using the Bray-1 method. Total N was determined by regular macro-Kjeldahl method while the organic matter was determined using the wet oxidation method.

The poultry manure (PM) used for experiment was from the government poultry farm at Alabata village, Odeda Local Government Area of Ogun State, Nigeria. The PM was dried and analyzed by standard procedures for the following characteristics: total P 24.80 g kg^{-1}; total N 20.00 gkg^{-1}; NH_4-N 1.40%; organic C 26.5%; C:N 18.9; Na 0.42%; K 0.72%; Ca 0.21%; Mg 0.16%; Zn 50.00 mg kg^{-1}; Cu 90.00 mg kg^{-1}; Mn 30.00 mg kg^{-1}.

The field experiment was conducted in 2004 and 2005 as a factorial experiment arranged as Randomized Complete Block Design (RCBD) with three replicates. The treatments consisted of three nitrogen rates (0, 50 and 100 kg N ha^{-1}) applied as urea (46%N); three rates of phosphorus (0, 30 and 60 kg P ha^{-1}) applied as single superphosphate (18% P_20_5) and two rates of poultry manure (0, 5 t ha^{-1}). Soybean (*Glycine* max, variety TGX 1448-2E) was introduced earlier in the season to precede maize cultivation. It was sown by drilling and spaced 30cm apart. At 12 weeks after planting, the pods were harvested while the stovers (residues) were incorporated into the soil. The amount of residue incorporated was estimated at 5 t ha^{-1}.

Two maize seeds (*Zea* mays, variety DMR-ESR-Y) were planted per hole and later thinned to one per stand at two weeks after emergence. The planting distance was 25cm by 75cm. Each plot size was 3m x 5m and the plant population was 53,333 maize plants per ha. All plots received basal application of 30 kg K ha^{-1} as muriate of potash. Plots receiving poultry manure had the manure worked into the soil two weeks before planting, weeding was done manually with native hoe at three weeks after planting (3WAP) and seven weeks after planting (7WAP). Twenty leaves were taken from each plot at tarselling for tissue analysis. The plant samples were dried to constant weight and analyzed for N and P. Plot by plot surface soil samples (0-20cm) were taken twice and the samples were analyzed for N, P, organic carbon, pH and exchangeable bases using methods previously described.

The data collected were subjected to analysis of variance using the Statistical Analysis System. Means were separated by Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Some physical and chemical properties of the soil used for the study are presented in Table 1. The soil is moderately acidic (pH 5.8) with low exchangeable bases (CEC 3.06 cmol kg^{-1}) and low available phosphorus. The values for total N (0.9 g kg^{-1}), soil organic matter (15.7 g kg^{-1}) also fall within the critical low range in soils of Western Nigeria as published by Adepetu (1986). With low N, low organic matter, low P, and low CEC, it is obvious that the soil is inherently low in fertility and would therefore inevitably have to rely on soil amendments for meaningful and sustainable agricultural productivity.

Table 1: Some physical and chemical properties of the soils used for the field experiment.

Parameters	**Values**
pH (H_2O)	5.80
Av.P (mg kg^{-1})	9.50
Na (cmol kg^{-1})	0.83
K (cmol kg^{-1})	0.12
Ca (cmol kg^{-1})	1.10
Mg (cmol kg^{-1})	0.89
H	0.12
ECEC (cmol kg^{-1})	3.06
% Base saturation	96.08
N (g kg^{-1})	0.9
O.M (g kg^{-1})	15.7
SILT (%)	20.10
CLAY (%)	11.00
SAND (%)	68.90

The effect of treatments on some plant and soil characteristics are presented in Tables 2 and 3 for years 2004 and 2005 respectively. Of all the amendments, manure had the greatest impact on organic matter build up. In 2004, at an application rate of 5 t ha^{-1}, it accounted for 49.1% increase in soil organic matter build up. This however reduced slightly in 2005 to 41.3%. The impact of N-fertilizer on soil organic matter build up was next to that of manure. It accounted for 22.6% increase in 2004 and 22.6% increase in 2005. Unlike manure and N-fertilizer, the impacts of legume and P-fertilizer on soil organic matter build up were slight. Only the interaction of manure and nitrogen fertilizer on soil organic matter was significant in 2004 while in 2005, only the interaction of legume and manure was significant. Manure therefore appears to be a controlling factor in organic matter build-up in soils. In the LxM interaction (Table 4) organic matter increased by 62.3% in 2005 when legume was combined with 5 t ha^{-1} manure over no legume-no manure interaction. In the MxN interaction (Table 5), organic matter increased by 80.2% in 2004 when 5 t ha^{-1} manure was combined with 100 kg N ha^{-1} fertilizer over control.

Table 2: Effect of treatment rates on some plant and soil characteristics in the field (2004).

Treatments	OM (g kg^{-1})	pH	Soil P (mg kg^{-1})	Soil N (g kg^{-1})	Plant P (%)	Plant N (%)	CEC (cmol kg^{-1})
Legume							
Without	15.33^{b}	6.48^{a}	4.94^{b}	1.43^{b}	0.46^{b}	0.56^{b}	2.21^{a}
With	16.59^{a}	6.49^{a}	5.14^{a}	1.51^{a}	0.47^{a}	0.58^{a}	2.21^{a}
Manure							
0	12.82^{b}	6.46^{a}	4.51^{b}	1.12^{b}	0.44^{b}	0.53^{b}	2.15^{b}
5	19.11^{a}	6.51^{a}	5.57^{a}	1.82^{a}	0.49^{a}	0.61^{a}	2.27^{a}
Nitrogen							
0	14.11^{c}	6.45^{b}	4.63^{c}	1.14^{c}	0.44^{c}	0.52^{c}	2.18^{c}
50	16.45^{b}	6.55^{a}	5.08^{b}	1.49^{b}	0.47^{b}	0.57^{b}	2.22^{b}
100	17.33^{a}	6.45^{b}	5.41^{a}	1.77^{a}	0.48^{a}	0.62^{a}	2.23^{a}
Phosphorus							
0	15.20^{b}	6.47^{a}	4.13^{c}	1.37^{c}	0.44^{c}	0.55^{c}	2.20^{b}
30	16.27^{a}	6.51^{a}	5.13^{b}	1.45^{b}	0.47^{b}	0.57^{b}	2.21^{b}
60	16.44^{a}	6.49^{a}	5.86^{a}	1.58^{a}	0.49^{a}	0.59^{a}	2.22^{a}
LxM	NS	NS	0.018	NS	NS	NS	NS
LxN	NS	0.036	NS	NS	NS	0.0002	NS
LxP	NS	NS	NS	NS	0.048	NS	NS
MxN	0.003	NS	0.002	NS	NS	0.0035	NS
MxP	NS	0.0012	NS	NS	NS	NS	NS
NxP	NS	0.0008	NS	NS	NS	NS	NS
LxMxN	NS	0.007	NS	0.043	NS	NS	NS
LxMxP	NS	NS	NS	NS	NS	NS	NS
LxNxP	NS	NS	NS	NS	NS	NS	NS
MxNxP	NS	0.0028	NS	NS	NS	NS	0.037

Figures having the same letter(s) as superscripts within a column are not significantly different at $P < 0.05$. L=legume; M=manure; N=nitrogen; P=phosphorus.

Table 3: Effect of treatment rates on some plant and soil characteristics in the field (2005).

Treatments	OM (g kg^{-1})	pH	Soil P (mg kg^{-1})	Plant P (%)	Soil N (g kg^{-1})	Plant N (%)	CEC (cmol kg^{-1})
Legume							
Without	15.54^{b}	6.61^{a}	4.83^{a}	0.46^{a}	1.15^{b}	0.52^{b}	2.37^{b}
With	17.62^{a}	6.63^{a}	4.87^{a}	0.46^{a}	1.36^{a}	0.56^{a}	2.43^{a}
Manure							
0	13.74^{b}	6.69^{a}	4.51^{b}	0.44^{b}	1.03^{b}	0.51^{b}	2.27^{b}
5	19.42^{a}	6.55^{b}	5.19^{a}	0.48^{a}	1.47^{a}	0.57^{a}	2.52^{a}
Nitrogen							
0	14.82^{c}	6.68^{a}	4.61^{c}	0.44^{b}	1.07^{c}	0.50^{c}	2.34^{c}
50	16.74^{b}	6.58^{b}	4.88^{b}	0.46^{a}	1.25^{b}	0.54^{b}	2.38^{b}
100	18.18^{a}	6.59^{b}	5.06^{a}	0.47^{a}	1.43^{a}	0.57^{a}	2.47^{a}
Phosphorus							
0	15.89^{c}	6.65^{a}	4.19^{c}	0.42^{c}	1.18^{b}	0.52^{c}	2.36^{b}
30	16.62^{b}	6.61^{a}	4.92^{b}	0.46^{b}	1.26^{a}	0.54^{b}	2.40^{a}
60	17.23^{a}	6.60^{a}	5.44^{a}	0.49^{a}	1.31^{a}	0.56^{a}	2.43^{a}
LxM	0.003	NS	NS	NS	NS	NS	0.0083
LxN	NS	0.029	0.0054	0.019	NS	NS	0.0058
LxP	NS	NS	0.0205	NS	NS	NS	NS
MxN	NS	NS	NS	<0.0001	0.0005	0.0007	NS
MxP	NS	NS	0.0017	NS	NS	NS	NS
NxP	NS	NS	0.0078	NS	NS	NS	NS
LxMxN	NS	NS	0.0019	NS	NS	NS	NS
LxMxP	NS	NS	NS	NS	NS	NS	NS
LxNxP	NS	NS	NS	NS	NS	NS	NS
MxNxP	NS	NS	NS	NS	NS	NS	NS

Figures having the same letter(s) as superscripts within a column are not significantly different at $P < 0.05$. L=legume; M=manure; N=nitrogen; P=phosphorus

Table 4: Soil organic matter status (g kg^{-1}) as affected by legume and manure application in the field.

	2004		2005		Mean of two years	
Manure (t ha^{-1})	Without Legume	With Legume	Without Legume	With Legume	Without Legume	With Legume
0	12.14^{d}	13.50^{c}	12.41^{d}	15.08^{c}	12.28d	14.29c
5	18.53^{b}	19.69^{a}	18.68^{b}	20.15^{a}	18.60b	19.92a

Figures having the same letter(s) as superscripts within a column are not significantly different at P < 0.05

Table 5: Soil organic matter status (g kg^{-1}) as affected by manure and Nitrogen fertilizer application in the field.

	2004		2005		Mean of two years	
N fertilizer (kg ha^{-1})	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})
0	11.57^{e}	16.66^{c}	12.21^{f}	17.42^{c}	11.89^{f}	17.04^{c}
50	13.09^{d}	19.82^{b}	13.77^{e}	19.71^{b}	13.43^{e}	19.77^{b}
100	13.81^{d}	20.85^{a}	15.25^{d}	21.11^{a}	14.53^{d}	20.98^{a}

Figures having the same letter(s) as superscripts within a column are not significantly different at P < 0.05.

It is obvious from the foregoing, that the interactive effect of combined application of manure and N-fertilizer on soil organic matter build-up is more profound than their separate effects. It is possible therefore, that the efficiency of fertilizer N is aided by the presence of manure. This view is supported by Manyong *et al.* (2002), who were of the opinion that the use of animal manure may increase the efficiency of inorganic fertilizer by providing micronutrients not present in the inorganic fertilizer.

The soil pH was not affected significantly by any of the amendments in 2004. However, the application of N-fertilizer and manure affected soil pH significantly in 2005 although negatively. The pH reduced slightly (by 2%) with application of manure at 5 t ha^{-1} while it decreased by 1.3% when N-fertilizer application reached 100 kg N ha^{-1} (Tables 2 and 3). Although soil pH values were observed to increase slightly in 2005 over 2004, it cannot be said to follow any particular trend with the amendments and even their interactions. For example, in 2005, the no manure - no P fertilizer interaction resulted in the highest pH of 6.70 which dropped by 2.9% to 6.51 when 5 t ha^{-1} manure was combined with 60 kg P ha^{-1}. The situation was different however, in 2004 when the 5 t ha^{-1} manure and 60 kg P ha^{-1} combination resulted in the highest pH of 6.56 that dropped by 2.3% to 6.41 when P fertilizer reached 60 kg ha^{-1} without manure (Table 6)

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Table 6: Soil pH as affected by manure and phosphorus fertilizer application in the field.

P fertilizer (kg ha^{-1})	2004		2005		Mean of two years	
	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})	Without Manure (0 t ha^{-1})	With Manure (5 t ha^{-1})
0	6.51^{abc}	6.42^{bc}	6.70^{a}	6.60^{bc}	6.61^{a}	6.51^{b}
30	6.47^{abc}	6.54^{ab}	6.68^{ab}	6.53^{c}	6.57^{ab}	6.54^{ab}
60	6.41^{c}	6.56^{a}	6.68^{ab}	6.51^{c}	6.55^{ab}	6.53^{ab}

Figures having the same letter(s) as superscripts within a column are not significantly different at P < 0.05.

The very minimal variations in pH values observed generally is an indication of high buffering capacity of the soil. Soil pH is an important property that affects many functions in the soil. Its proper management therefore, may provide unexpected benefits by reducing the need for external inputs in agricultural production (Dick *et al.*, 2000).

The effects of treatments on plant content of P as presented in Tables 2 and 3 show that plant P was significantly affected by all the treatments in 2004 particularly manure and P-fertilizer where the increase in plant P in each case was 11.4%. However, while the effect of P-fertilizer on plant P increased further in 2005 to 16.6%, that of manure reduced to 9.1% indicating that P-fertilizer may be a stronger factor in plant uptake of P than manure. Nitrogen fertilizer also appears to be a factor in plant uptake of P as increase in plant P due to N fertilizer was 9.1% in 2004 but reduced to 6.8% in 2005 following the trend observed for manure. The effect of legume on plant uptake of P was the least. In 2004, it accounted for mere 2.2% increase in plant P while in 2005 there was no increase at all pointing to the fact that legume may not really be a factor in plant uptake of P. Of all the interactions studied in 2004, only the legume-P fertilizer interaction was significant for plant P. In 2005 however, the LxN and the MxN interactions were found to be significant for plant P. In 2004, the LxP interaction accounted for an increase of 13.9% in plant P at 60 kg ha^{-1} with or without legume (Table 7). The increase is therefore, suspected to be due only to the P-fertilizer component of the interaction.

Table 7: Plant concentration of P (%) in response to legume and phosphorus fertilizer application in the field.

P fertilizer (kg ha^{-1})	2004		2005		Mean of two years	
	Without Legume	With Legume	Without Legume	With Legume	Without Legume	With Legume
0	0.43^{d}	0.44^{c}	0.41^{c}	0.42^{c}	0.42^{d}	0.44^{c}
30	0.46^{b}	0.47^{b}	0.46^{b}	0.47^{b}	0.46^{b}	0.47^{b}
60	0.49^{a}	0.49^{a}	0.50^{a}	0.49^{a}	0.49^{a}	0.49^{a}

Figures having the same letter(s) as superscripts within a column are not significantly different at P < 0.05.

Plant uptake of N was significantly affected by all the treatments in the two years of study as shown in Tables 2 and 3. The effect of N fertilizer was however most pronounced followed by that of manure. In 2004, N fertilizer accounted for plant N increase of 19.2% when the level of application reached 100 kg N ha^{-1}. The effect however, dropped to

14.0% in 2005. The same trend was observed for manure which accounted for plant N increase of 15.1% in 2004 and 11.7% in 2005. The effect of legume followed a different trend. In 2004, legume accounted for 3.6% increase in plant N. This effect was however doubled in 2005 to 7.7% indicating that legume could be an important factor in plant N. Of all the interactions studied in 2004, only the LxN and the MxN interactions were significant in plant N. In 2005, only the MxN interaction was significant. In 2004, the MxN interaction accounted for an increase of 37.5% in plant N at 5 t ha^{-1} manure and 100 kg N ha^{-1} level of combination over the control (Table 8).

Table 8: Plant concentration of N (%) in response to manure and Nitrogen fertilizer application in the field.

	2004		2005		Mean of two years	
N fertilizer (kg ha^{-1})	**Without Manure (0 t ha^{-1})**	**With Manure (5 t ha^{-1})**	**Without Manure (0 t ha^{-1})**	**With Manure (5 t ha^{-1})**	**Without Manure (0 t ha^{-1})**	**With Manure (5 t ha^{-1})**
0	0.48^{e}	0.56^{cd}	0.45^{e}	0.54^{c}	0.47^{e}	0.55^{c}
50	0.54^{d}	0.60^{b}	0.52^{d}	0.57^{b}	0.53^{d}	0.58^{b}
100	0.57^{c}	0.66^{a}	0.55^{c}	0.60^{a}	0.56^{c}	0.63^{a}

Figures having the same letter(s) as superscripts within a column are not significantly different at $P < 0.05$.

The increase in plant N due to the interaction in 2005 was slightly lower (33.3%). In 2004, the LxN interaction accounted for an increase of 22% and 24% in plant N at 100 kg N ha^{-1} with or without legume respectively (Table 9) suggesting that the increase may actually be as a result of N fertilizer component of the interaction.

Table 9: Plant concentration of N (%) in response to legume and Nitrogen fertilizer application in the field.

	2004		2005		Mean of two years	
N fertilizer (kg ha^{-1})	**Without Legume**	**With Legume**	**Without Legume**	**With Legume**	**Without Legume**	**With Legume**
0	0.50^{d}	0.53^{c}	0.48^{d}	0.52^{c}	0.49^{e}	0.53^{d}
50	0.56^{bc}	0.58^{b}	0.53^{c}	0.56^{b}	0.54^{c}	0.57^{b}
100	0.62^{a}	0.61^{a}	0.56^{b}	0.59^{a}	0.59^{a}	0.60^{a}

Figures having the same letter(s) as superscripts within a column are not significantly different at $P < 0.05$.

It appears therefore, that manure and N fertilizer are major factors controlling plant uptake of N.

The effect of treatments on soil CEC (Tables 2 and 3) shows that for the two years of study, all the treatments had positive and significant effect on CEC apart from legume which had no effect in 2004. The increase in CEC due to manure in 2004 was 5.6%. This however, increased to 11.0% in 2005. The effect of N fertilizer on CEC followed similar pattern with an increase of 2.3% and 5.5% in 2004 and 2005 respectively. In 2004, legume had no effect at all on CEC. It however, accounted for an increase in CEC of 2.5% in 2005. The application of P fertilizer also accounted for an increase in CEC of 0.91% and 2.9% in 2004 and 2005 respectively. None of the interactions studied was significant for CEC in 2004. In 2005 however, both the legume-

manure and the legume- N fertilizer interactions were significant for CEC. In 2005, the legume-manure interaction accounted for an increase of 13.7% in CEC when legume was combined with 5 t ha^{-1} manure over the control (Table 10)

Table 10: Soil CEC (cmol kg^{-1}) as affected by legume and manure application in the field.

	2004		2005		Mean of two years	
Manure (t ha^{-1})	Without Legume	With Legume	Without Legume	With Legume	Without Legume	With Legume
0	2.14^{b}	2.15^{b}	2.26^{c}	2.29^{c}	2.20c	2.22c
5	2.27^{a}	2.27^{a}	2.47^{b}	2.57^{a}	2.37b	2.42a

Figures having the same letter(s) as superscripts within a column are not significantly different at $P < 0.05$.

Although the values for CEC in all the experimental plots remained low in 2005, the values were generally observed to be higher than what obtained in 2004. Also, at all levels of the legume-manure interactions, CEC was observed to be slightly higher in 2005 than in 2004. These observations are indications to the positive effects of soil amendments on soil properties.

CONCLUSION

The study has essentially shown that integrated application of organic and inorganic nutrient sources is beneficial to soil condition and nutrient uptake. The maintenance of soil properties, especially soil organic matter, soil pH and Cation Exchange Capacity (CEC) appear from the results of this study to benefit from the combined application of the soil amendments rather than by their separate applications. The efficiency of one amendment appears to be aided by the presence of another. Integrated application of nutrient sources is therefore, recommended both for efficient nutrient uptake and sustenance of soil quality.

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