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Soil Chemical Properties as Affected by Incorporated Legumes and Nitrogen in Soil with Maize (*Zea mays* L.) in a Semi-Arid Environment

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***Abstract* – Soil infertility is a critical constraint in crop production in savanna soils. Hence, there is a need to develop a cropping system which will enhance soil nutrient availability and usage. In a bid to address this, field experiments were conducted 2005, 2006 and 2007 wet seasons at the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, to evaluate the effect of incorporated short duration legume fallow and nitrogen levels on soil chemical properties. The treatments consisted of two maize varieties (SAMMAZ 12 and SAMMAZ 27) and five rates of nitrogen (0, 30, 60, 90 and 120kg N ha^{-1}) in the main plots while three green manure crops (Lablab (*Lablab purpureus*), Mucuna (*Mucuna pruriens*) and Soybean (*Glycine max* (L.) Merrill) and a weedy fallow were accommodated in the sub-plots. The plots with SAMMAZ 27 had more soil organic carbon, soil total N and soil C:N than plots with SAMMAZ 12 whereas plots with SAMMAZ 12 had more soil exchangeable Ca than plots with SAMMAZ 27. Application of 30 and 90 kg N ha^{-1} significantly increased soil organic carbon while application of 90 and 120 kg N ha^{-1} improved soil available P. Nitrogen application had no consistent effect on soil exchangeable Mg but significantly reduced soil pH and soil exchangeable K. Nitrogen addition had no significant effect on soil total N, soil C:N and soil exchangeable Ca. Incorporation of mucuna, lablab and soybean showed beneficial effects on soil chemical properties . Incorporation of green manure crops increased significantly soil organic carbon, soil total N and soil available P but reduced significantly the soil pH, soil C:N and soil exchangeable cations compared with weedy fallow.**

***Keywords* – Green Manure, Incorporation, Mineralization, Nitrogen, Varieties, Soil Chemical Properties.**

I. Introduction

The main challenge facing crop productivity in Savanna zone of Nigeria is poor soil fertility. Nigerian Savanna soils are low in organic carbon, total nitrogen, available phosphorus, effective CEC and exchangeable cations as well as clay and silt contents [1]. The situation is becoming worse year after year because the underlined issues like low fertilizer application, outright removal of crop residues, soil nutrient mining, less organic fertilizer usage and continuous intensive farming with less or no effort to rejuvenate the soil with organic manure. Nigeria was reported to have lost 57kg soil nutrients per year between 2002-2004 cropping seasons [2]. Cropland quality and fertility may have also influenced the poor year performance in the last one-two decades in Nigeria [3]. Addition of organic fertilizers like green manure will go a long way to improve crop land quality and fertility.

The current global drive for sustainable food crop production can only be achieved with increasing use of organic fertilizer. It is a known fact that organic matter has been the main factor in the sustainability of soil fertility and productivity. Green manure is a well-known generator of organic matter. Green manure, apart from increasing soil nitrogen [4], releases phosphorus [5], [6], maintains and renews the soil organic matter and improves the soil physical and chemical characteristics [7]. Incorporation of crop residues was beneficial to the soil in terms of increased soil organic concentration (SOC) that is not only beneficial to soil in relation to agriculture but also represents a sequestration of carbon from atmospheric carbon dioxide [8]. The potential benefits of incorporating green manure crops into soil cannotbe over emphasis, Walter [9] reported that when green manure crops are ploughed into the soil, their residues help to increase availability of phosphate and trace elements to the succeeding crops due to the lowering of the soil pH brought about by the carbon dioxide produced in the process of decomposition.Therefore, adoption of green manure cropping system, which is environmentally friendly and a soil improver, will be the best option for sustainable maize production in northern Guinea Savanna [10].

The green manure materials may either be obtained from quick growing green manure crops grown in situ or harvested from elsewhere for incorporation into the soil. The amount of nutrients provided by plant materials are determined by the production rate and nutrient concentrations depending on climate, soil type, plant part, plant density and management regimes [11]. It has been equally reported that the rate of biological decomposition and consequent release of nutrient varies with ambient conditions such as temperature, moisture, aeration, pH and other factors affecting microbial activity [12], [13]. Incorporation of legumes before flowering makes available immature legume biomass for quick decomposition. It has been reported that immature plant material usually decomposes faster than mature material [14]. Decomposition and mineralization of nutrients in the incorporated legumes will definitelyinfluence the chemical property of soil which will have positive effects on nutrient status and fertility of the soil. Therefore, the objective of this study was to determine the effect of

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incorporated short duration legume fallow and nitrogen levels on chemical properties of soil grown with two maize varieties.

II. Materials and Methods

The field experiments were carried out in the wet seasons of 2005, 2006 and 2007 at the research farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria (11° 11[1] N, 07° 38[1] E, 686 m above sea level) in the northern Guinea Savanna zone of Nigeria. The annual rainfall for the duration of the study in 2005, 2006, and 2007 was 790.4, 1086.7 and 900.4mm, respectively. The physico-chemical analysis of the top soil (0-30cm depth) of the experiment site before planting in 2005 as determined by standard procedures showed that the soil was loam with the following properties: pH (0.01M $CaCl_2$), 5.0; organic carbon, 5.3 g kg^{-1}; total nitrogen, 0.53 g kg^{-1}; available phosphorus, 12.25 mg kg^{-1}; and exchangeable cations (cmol kg^{-1}) of Ca^{2+}, 1.80; Mg^{2+}, 0.36; K^+, 0.14; and Na^+, 0.11; and CEC, 4.8 cmol kg^{-1}. The chemical analysis of the incorporated green manure crops is shown in Table 1. The treatments consisted of two maize varieties (SAMMAZ 12 and SAMMAZ 27), five levels of N (0, 30, 60, 90, and 120 kg N ha^{-1}), and three green manure crops (*Lablab purpureus, Mucuna pruriens and Glycine max* (L.) Merrill) and a weedy fallow. The experiment was laid out in a split-plot design with nitrogen and variety as main plot treatment and green manure as the sub plot treatment. The experiment was replicated three times.

Leguminous green manure crops were planted on the flat with narrower inter-row spacing of 37.5 cm. The lablab was sown at two stands per hole at 20 cm within row and mucuna was sown at one stand per hole at 20 cm within row. The soybean was planted drilled. The green manure crops were incorporated at 49 days (7 weeks) after planting. After 3 days of incorporation, maize seeds were planted with two or three seeds per hole at a spacing of 25 cm on the ridges of 75 cm apart. The maize seedlings were thinned to one seedling per stand at two weeks after sowing. The experimental plot consisted of six ridges of 4.5 m apart and 4m long (gross plot) and net plot was 3 m x 3 m (9 m^2).

Table 1: Chemical analysis of the shoot of the green manure crops used in the study from 2005-2007.

	N%	P%	K%	C%	C:N
Weedy Fallow	1.64	0.86	1.80	62.11	38
Mucuna	3.32	0.59	0.88	43.94	14
Lablab	3.53	0.61	1.17	49.79	14
Soybean	3.34	0.64	1.25	44.97	13

The green manure crops received 20 kg P_2O_5 ha^{-1} and 10 kg N ha^{-1} to boost their growth. Application of nitrogen fertilizer as urea (46%N) to the maize plants was done at 2 and 6 weeks after sowing (WAS) according to treatment. Basal applications of 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} were done at sowing. Weeds were controlled using Paraquat (Gramaxone) at 3 litres ha^{-1} to kill weeds that were not properly incorporated and hoe weeding was done at 6WAS.

Soil sample collections from the depth of 0-30 were taken in each plot according to the treatments at the harvest of maize in 2005, 2006 and 2007 and were analyzed as described below. Soil pH was determined in 0.01M$Cacl_2$ by using a soil solution ratio of 1:2.5 by means of a Philip analogue pH meter. The soil was determined using the pH meter [15]. The organic carbon content of soil was determined by the wet oxidation method of Walkley-Black as described by [16]. The total nitrogen content of the soil was determined by Micro Kjeldahl procedure [17]. C;N was computed as ratio of N to C. Available phosphorus (P) was extracted by the Bray 1 method. The P concentration in the extract was determined colorimetrically by using the Spectronic 20 and absorption was read-off as described by [18] and modified by [19]. Exchangeable K, Ca and Mg were extracted using ammonium acetate. K was determined on flame photometer and Ca and Mg by Atomic Absorption Spectrophotometer (AAS).

The data collected were subjected to statistical analysis of variance (ANOVA) as described by [20] using SAS package version 9.0 of statistical analysis [21]. The differences among treatment means were separated using Duncan's Multiple Range Test (DMRT) [22]. Effects were considered statistically significant at 5% level of probability.

III. Results

A. Variety Effect

Variety effect was not significant on soil pH (Table 2), soil available P (Table 4), soil exchangeable K (Table 4) and soil exchangeable Mg (Table 5). Variety effect was significant on soil organic carbon in the three years of study and combined mean (Table 2), Soil total N in 2007 (Table 3) and soil C:N in 2005, 2006 and combined mean (Table 3) where plots with SAMMAZ 27 gave significantly higher soil organic carbon in all the three years and combined mean (Table 2), Soil total N in 2007 (Table 3) and soil C:N in 2005, 2006 and combined mean (Table 3) than plots with SAMMAZ 12. Variety effect on soil exchangeable Ca was significant in 2007 where plots with SAMMAZ 12 gave significantly higher soil exchangeable Ca than plots with SAMMAZ 27(Table 5).

B. Effect of Nitrogen Treatment.

Nitrogen application significantly influenced soil pH at harvest in 2006, 2007 and in combined mean (Table 2). Application nitrogen significantly reduced soil pH with exception of 30 kg N ha^{-1} and plots without nitrogen application significantly which significantly increased soil pH (Table 2). Application of 30 kg N ha^{-1} produced significantly higher soil organic carbon than application of 60 and 120 kg N ha^{-1} in all the three years of study and their combined mean with exception of application of 0 and 60 kg N ha^{-1} in 2006 (Table 2). Nitrogen application was not significant on soil total N in all the period of study and combined mean (Table 3). Nitrogen application was significantly affected soil C:N at harvest in 2005 only(Table 3) where no N control had significantly higher soil C:N than other levels of N with exception of 60 kg N ha^{-1} that was at par with no N control and other levels of N. Application of nitrogen beyond 30 and 60 kg N ha $^{-1}$ did not significantly increase soil available P in 2005 and 2006, respectively (Table 4). In 2007, Application of 30 kg N ha^{-1} significantly decreased soil available P but further N addition produced no further increase on soil available P (Table 4). However, application 90 kg N ha^{-1} was statistically similar to zero N control on soil available P (Table 4). In combined analysis, application of 30 kg N ha^{-1} produced no significant difference on soil available P but further N addition to 60 and 90 kg N ha^{-1} gave 20.6 and 40.9% higher soil available P than no N control while further addition of 120 kg was at par with application of 90 kg N ha^{-1}(Table 4) .

Application of nitrogen was significant on soil exchangeable K in 2006 and in combined mean (Table 4). In 2006, increasing N level significantly reduced soil exchangeable K up to 120 kg N ha^{-1}; although there was no significant difference between application of 60 and 90 kg N ha^{-1} on soil exchangeable K (Table 4). In combined mean, application of 30 and 60 kg N ha^{-1} had no significant difference on soil exchangeable K while application of 90 and 120 kg N ha^{-1} significantly reduced soil exchangeable K by 13.3 and 20% when compared with no N control (Table 4). Effect of nitrogen on soil exchangeable Ca was significant only in 2007 (Table 5). In 2007, application of 90 kg N ha^{-1} resulted in higher soil exchangeable Ca than 30 and 120 kg N ha^{-1} (Table 5). Application of nitrogen on maize was significant in 2005, 2007 and combined mean (Table 5). In 2005, increasing N level did not significantly influence soil exchangeable Mg up to 90 kg N ha^{-1} but application of 120 kg N ha^{-1} significantly reduced soil exchangeable Mg (Table 5) . In 2007 and combined mean, increasing N level from 0 to 30 kg N ha^{-1} significantly increased soil exchangeable Mg by 71.4 and 20% over the control, respectively. However, further N addition did not significantly increase soil exchangeable magnesium (Table 5).

Table 2: Influence of green manure and nitrogen on soil pH and soil organic carbon in soil grown with two maize varieties in 2005, 2006, 2007 and combined

	Soil pH				Soil organic carbon(g kg^{-1})			
Treatment	2005	2006	2007	Combined	2005	2006	2007	Combined
Variety								
SAMMAZ 12	5.23	4.57	4.64	4.81	7.05b	6.20b	6.72b	6.66b
SAMMAZ 27	5.18	4.59	4.65	4.81	7.47a	7.06a	7.19a	7.24a
SE±	0.041	0.032	0.032	0.020	0.101	0.126	0.113	0.066
Nitrogen Kg ha^{-1}								
0	5.37	4.87a	4.93a	5.06a	7.02b	6.43ab	6.74b	6.73bc
30	5.23	4.75a	4.63b	4.87b	7.66a	7.07a	7.32a	7.35a
60	5.14	4.36b	4.52b	4.67c	7.06b	6.81a	6.76b	6.88b
90	5.11	4.48b	4.57b	4.72c	7.47ab	6.78a	7.50a	7.25a
120	5.19	4.44b	4.58b	4.74c	7.11b	6.06b	6.46b	6.54c
SE±	0.064	0.05	0.50	0.032	0.159	0.199	0.178	0.104
Green manure								
Weedy fallow	5.22	4.54	4.77a	4.84a	7.60	6.54b	6.59b	6.91
Mucuna	5.20	4.58	4.59bc	4.79bc	7.15	6.99a	6.82ab	6.98
Lablab	5.20	4.58	4.55c	4.78c	7.12	6.64ab	7.16a	6.98
Soybean	521	4.62	4.67b	4.83ab	7.18	6.34b	7.26a	6.93
SE±	0.019	0.023	0.033	0.015	0.170	0.128	0.164	0.09

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

C. Effect of Green Manure Treatment

Incorporation of mucuna, lablab and soybean significantly reduced soil pH in 2007 and combined mean when compared with incorporation of weedy fallow (Table 2) with exception of soybean incorporation which was at par with weedy fallow incorporation on soil pH. Incorporation of legume green manure crops significantly improved soil organic carbon in 2006 and 2007(Table 2). However, lablab and soybean green manure in 2006 and mucuna green manure in 2007 were not significantly different from weedy fallow on soil organic carbon (Table 2). Incorporation of mucuna, lablab and soybean significantly increased soil total N in all the three years of study and their combined mean (Table 3). However, there was no significant difference among the green manure crops on soil total N. In combined mean, incorporation of mucuna, lablab and soybean significantly increased soil total N by 25.4, 25.4 and 20.9% over weedy fallow, respectively (Table 3). Incorporation of green manure crops significantly influenced soil C:N in 2005, 2006 and combined mean (Table 3). Plots buried with weedy fallow had significantly higher soil C:N than plots buried with legume green manure crops in 2005 and combined mean (Table 3). However in 2006, plots that received mucuna green manure had significantly higher soil C:N than plots that received soybean green manure although at par with other green manure treatment (Table 3).

In 2005, incorporation of mucuna and lablab produced similar but significantly lower soil available P than plots that received soybean green manure but at par with weedy fallow (Table 4). In 2006, plots that received lablab green manure had significantly higher soil available P than plots that received mucuna green manure although at par with other green manure treatments (Table 4). In 2007, incorporation of lablab and soybean produced similar but higher soil available P than plots that received mucuna and weedy fallow (Table 4). In combined mean, incorporation of lablab and soybean produced similar but higher soil available P than mucuna and weedy fallow (Table 4). In 2006, 20006 and combined mean, incorporation of legume green manure crops produced similar but significantly lower soil exchangeable K than plots that received weedy fallow except soybean green manure that was at par with weedy fallow in 2007 (Table 4). Incorporation of green manure was significant on soil exchangeable Ca only in 2007 (Table 5) where incorporation of green manure significantly reduced soil exchangeable Ca but there was no significant difference among the green manure crops. Incorporation of mucuna, lablab and soybean significantly reduced soil exchangeable Mg in 2006, 2007 and combined mean compared with weedy fallow but there was no significant difference among legume green manure crops (Table 5).

Table 3: Influence of green manure and nitrogen on soil total N and soil C: N organic carbon in soil grown with two maize varieties in 2005, 2006, 2007 and combined.

	Soil Total N(g kg^{-1})				**Soil C:N**			
Treatment	2005	2006	2007	Combined	2005	2006	2007	Combined
Variety								
SAMMAZ 12	0.78	0.71	0.87b	0.79	10.33b	9.92b	9.55	9.94b
SAMMAZ 27	0.76	0.73	0.90a	0.79	11.59a	12.66a	9.18	11.14a
SE±	0.012	0.019	0.009	0.008	0.285	0.581	0.4	0.253
Nitrogen Kg ha^{-1}								
0	0.74	0.72	0.87	0.77	12.17a	10.61	10.24	11.00
30	0.80	0.69	0.86	0.78	10.62b	11.68	9.89	10.73
60	0.74	0.71	0.91	0.78	11.39ab	13.04	8.36	10.93
90	0.78	0.78	0.90	0.82	10.30b	10.20	10.18	10.23
120	0.77	0.72	0.90	0.79	10.32b	10.94	8.15	9.80
SE±	0.02	0.03	0.015	0.013	0.451	0.918	0.632	0.401
Green manure								
Weedy fallow	0.63b	0.61b	0.78b	0.67b	13.15a	11.97ab	9.64	11.59a
Mucuna	0.85a	0.76a	0.92a	0.84a	9.60c	12.08a	9.27	10.32b
Lablab	0.80a	0.76a	0.95a	0.84a	10.92b	10.61ab	8.87	10.13b
Soybean	0.78a	0.75a	0.91a	0.81a	10.16bc	10.49b	9.68	10.11b
SE±	0.024	0.03	0.022	0.015	0.420	0.507	0.469	0.269

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Table 4: Influence of green manure and nitrogen on soil available P and soil exchangeable K in soil grown with two maize varieties in 2005, 2006, 2007 and combined.

	Soil Available P(mg kg^{-1})				**Soil Exchangeable K(cmol kg^{-1})**			
Treatment	2005	2006	2007	Combined	2005	2006	2007	Combined
Variety								
SAMMAZ 12	20.98	23.15	21.18	21.77	0.36	0.23	0.20	0.26
SAMMAZ 27	20.66	22.19	21.30	21.38	0.39	0.23	0.21	0.28
SE±	1.338	1.575	0.874	0.748	0.013	0.004	0.011	0.006
Nitrogen Kg ha^{-1}								
0	13.25b	15.54b	25.67a	18.15c	0.38	0.29a	0.22	0.30a
30	20.65a	17.02b	20.84b	19.50bc	0.37	0.24b	0.25	0.29ab
60	22.45a	24.60a	18.61b	21.89b	0.41	0.22c	0.18	0.27ab
90	25.87a	28.76a	22.09ab	25.58a	0.34	0.22c	0.22	0.26bc

120	21.88a	27.42a	18.99b	22.76ab	0.38	0.18d	0.25	0.24c
SE±	2.115	2.49	1.381	1.182	0.02	0.006	0.017	0.009
Green manure								
Weedy fallow	21.85ab	20.69ab	15.33c	19.29b	0.39	0.26a	0.23a	0.29a
Mucuna	17.54b	19.58b	20.93b	19.35b	0.37	0.23b	0.19b	0.26b
Lablab	19.37b	25.69a	24.52a	23.19a	0.36	0.22b	0.19b	0.26b
Soybean	24.52a	24.71ab	24.19a	24.47a	0.38	0.22b	0.21ab	0.27b
SE±	1.487	1.752	1.048	0.842	0.1	0.008	0.013	0.006

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Table 5: Influence of green manure and nitrogen on soil exchangeable Ca and soil exchangeable Mg in soil grown with two maize varieties in 2005, 2006, 2007 and combined.

	Soil Exchangeable Ca(cmol kg^{-1})				**Soil Exchangeable Mg(cmol kg^{-1})**			
Treatment	2005	2006	2007	Combined	2005	2006	2007	Combined
Variety(V)								
SAMMAZ 12	1.96	1.15	0.93a	1.35	0.41	0.33	0.37	0.37
SAMMAZ 27	2.04	1.26	0.79b	1.36	0.41	0.33	0.30	0.35
SE±	0.046	0.045	0.035	0.024	0.011	0.007	0.025	0.009
Nitrogen(N) Kg ha^{-1}								
0	1.97	1.20	0.86abc	1.34	0.43a	0.34	0.28b	0.35b
30	1.97	1.23	0.74c	1.31	0.43a	0.34	0.48a	0.42a
60	2.08	1.08	0.93ab	1.36	0.43a	0.32	0.31b	0.36b
90	1.94	1.20	0.98a	1.37	0.41a	0.33	0.30b	0.34b
120	2.04	1.31	0.79bc	1.38	0.36b	0.34	0.29b	0.33b
SE±	0.072	0.072	0.055	0.039	0.017	0.011	0.04	0.015
Green manure (G)								
Weedy fallow	2.03	1.14	0.93a	1.37	0.42	0.36a	0.43a	0.40a
Mucuna	1.93	1.30	0.83b	1.36	0.43	0.33b	0.29b	0.35b
Lablab	1.98	1.22	0.84b	1.35	0.40	0.31b	0.28b	0.33b
Soybean	2.07	1.15	0.82b	1.35	0.41	0.33b	0.32b	0.35b
SE±	0.07	0.05	0.022	0.03	0.007	0.009	0.039	0.013

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

IV. Discussion

Plots grown with SAMMAZ 27 had more soil organic carbon, soil total N and soil C:N than plots grown with SAMMAZ 12. This could be that SAMMAZ 12 was more efficient in making used of the soil organic carbon, soil total N and soil C:N in plots grown with SAMMAZ 12 than SAMMAAZ 27 in plots grown with SAMMAZ 27. Babalola *et al.* [23] when working on two varieties of tomatoes (UC 82B and Beske) and compost manure reported that the significant varietal differences observed on soil properties 6 and 12 MACA tend to suggest that the two tomato varieties had remarkable differences in their contributions to soil improvement with or without compost amendment. Plot grown with SAMMAZ 12 had more soil exchangeable Ca than plots grown with SAMMAZ 27 which couid be that SAMMAZ 27 was better in utilization of soil exchangeable Ca. Plots grown with both varieties exhibited similarity on soil pH, soil available P, soil exchangeable K and soil exchangeable Mg. This could be that both varieties were similar in their utilization of these soil nutrients.

Significant reduction observed in soil pH after application of N could be attributed to the oxidation of N fertilizers, for example the conversion of urea to ammonium produces H^+ that decreases the soil pH during reduction reaction [24]. Application of 30 and 90 kg N ha^{-1} gave significant increases in soil organic carbon. These increases in soil organic carbon could be attributed to the fact that mineral N enhances microbial decomposition of plant residues [25] - [28], which will definitely increase soil organic carbon. Lack of response of soil total N and C:N in most cases to applied N could probably be due to the dilution effect of added N because some quantities of soil N had been used up by the maize plants from the soil which greatly reduced the amount of soil total N coupled with the fact that soil sampling was done at harvest each year when most of the N must have been used up, leached and eroded. [29] reported that none of the N fertilizers used added residual N to the soil and it was affirmed that values of total N and nitrates at the end of the crop cycle were similar to those from pre-sowing.

Significant increases observed in soil available P after N application could be attributed to the role of N in mediating the utilization of phosphorous, potassium and other elements in plant [30]. Again, [31] reported a decline in extractable P in soil with N application up to 84 kg N ha^{-1}, while extractable P increased with high N rates. Reduction observed in soil exchangeable K after N fertilization could be that it had been accumulated in the maize plant which could have reduced the amount of soil exchangeable K in the soil. The lack of response of soil exchangeable Ca to applied N could probably be that it had been used up by maize plants. The inconsistent effect of nitrogen application on soil exchangeable Mg could be due to the fact that soil sampling was done at harvest each year when most of these elements must have been used up, leached and eroded.

The reduction in soil pH after legumes incorporation could be that the decomposition of biomass of crop residues released organic acids which probably caused the pH depression [8]. Similar result was obtained by [32] where it was stated that reduction in exchangeable cations was perhaps be the reason for lowering of the pH. The improvement in soil organic carbon could be attributed to decomposition and mineralization of the incorporated mucuna, lablab and soybean, hence, soil organic carbon content was improved, thus enhancing the soil organic matter which has been the main factor in the sustainability of soil fertility and productivity. Some researchers like [33], [34], and [35] observed significant improvement in soil organic carbon and soil organic matter after legume incorporation. Incorporation of mucuna, lablab and soybean was beneficial to the soil in terms of increased soil total nitrogen which could be attributed to N fixation by rhizobial strain in root nodules of the incorporated legumes and amount of N mineralized from incorporated legumes. This result was not a surprise because of the high N content (average of 3.32 – 3.53% N) and low C:N ratio (average of 14-15:1) of the incorporated legume materials compared to weedy fallow with low N content (average of 1.64% N) and high C:N ratio (average of 38:1). This means better quality materials were decomposed quickly because of the low C:N ratio which necessitated the quick release of mineralized N. [8] attributed the increase in soil total N to the quality (i.e. nutrient composition) and small C:N ratio, which is one indication of the rate of decomposition in the soil.

The reduction in C:N ratio due to incorporation of mucuna, lablab and soybean could be attributed to higher microbial degradation of the organic materials. The low C:N ratio of the incorporated legumes enhanced faster decomposition of organic materials in legumes incorporated plots than weedy fallow plots with higher C:N ratio. Soil nutrients are better released in soil with low C:N ratio than soil with higher C:N ratio. The increase in soil available P in plots incorporated with legumes could be attributed to high microbial activity induced by the added organic residues which speed up P cycling [36]. Another reason is that decomposition of organic materials releases organic acids which could dissolve inorganic P compounds [37]. The reduction in soil exchangeable K, Ca and Mg after incorporation of mucuna, lablab and soybean compared to weedy fallow might be due to high cation requirement of N-fixing plants [38], which decreased the amount of exchangeable cations in the rhizosphere.

V. Conclusion

This Study has showed that there no much difference in the utilization of the added nutrients by both SAMMAZ 12 and SAMMAZ 27. This indicates that both varieties are suitable for this type of cropping system. Application of 30 and 90 kg N ha^{-1} significantly increased soil organic carbon while application of 90 and 120 kg N ha^{-1} improved soil available P. However, application of nitrogen significantly reduced soil pH and soil exchangeable K. In addition, nitrogen fertilization had no consistent effect on soil exchangeable Mg. However, nitrogen fertilization had no significant effect on soil total N, soil C:N and soil exchangeable Ca. Incorporation of mucuna, lablab and soybean improved soil organic carbon, soil total N and soil available P compared with weedy fallow which gave lower values. However, incorporated legumes reduced significantly soil pH, soil C:N and soil exchangeable cations compared with weedy fallow with higher values. This study has further showed that organic material addition to soil helps to overcome the decline in soil organic matter which is the bedrock of soil life, and generate nutrients biologically for sustainable crop production.

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