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Evaluation and Enhancement of Available Micronutrients Status of Cultivated Soil of Nigeria Guinea Savanna Using Organic and Inorganic Amendments.

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Abstract**:** Field experiments were conducted during years 2010 and 2011 cropping seasons of Nigerian Guinea Savanna, in which eighty-one surface soils (0-20 cm depth) were collected before, in-between and after the cropping seasons. The soils were analysed for status of pH, OC, CEC, available Zn, Cu, Fe and Mn. Initial status of the soil pH, OC and CEC were 5.7 (moderately acidic), 4.62 g kg^{-1} and 1.6 cmol(+)/kg respectively, while those of Zn, Cu, Fe and Mn were 0.18, 0.1, 22.5 and 21.5 mg kg^{-1} respectively. The soils were deficient in all the studied properties except Fe and Mn which were in high concentrations in the soils. Applications of organic and inorganic amendments to the soils significantly improved soil properties through increment in the soil pH and organic carbon status. The effect of the inorganic amendment was immediate while that of the organic was on residual basis. By the end of the second season, status of Zn (0.75 mg kg^{-1}) and Cu (0.28 mg kg^{-1}) had significantly increased above the critical limit, from residual effect of application of 10 t ha^{-1} of fertiplus and compost plus respectively, while the excessively high concentrations of Fe and Mn in the soils were also amended.
Keywords- *Amendment, Enhancement, Evaluation, Micronutrients, Savanna.*

I. Introduction

Micronutrients are essential elements required by plants in very small amounts for growth and development. They include iron, zinc, copper, boron, manganese, molybdenum and chlorine. Micronutrients play a vital role in gene expression, biosynthesis of protein, nucleic acids, growth substances, metabolism of carbohydrates and lipids through their involvement in various plant enzymic systems and other physiologically active molecules (Rangel, 2003). Generally, studies on micronutrients status of Nigerian soils have been neglected in the past due to non- prevalence of their deficiency symptoms. This has made the information on soil micronutrient status of Nigeria savanna soils scanty. Lombin (1983), Kparmwang *et. al.* (1995) and Adeboye (2003), reported that limited studies have been conducted on the micronutrients status of soils within the savanna zone of Nigeria. However, the few investigations carried out so far have revealed micronutrient deficiency in some Nigerian savanna soils (Lombin (1983a, 1983b, 1985a). Depletion of micronutrients in Nigerian savanna soils has resulted from intensively cultivated soil with high nutrient-demanding crops, highly weathered rocks and leaching. Mustapha and Loks (2005), reported that the use of new high yielding crop varieties which are nutrient demanding have unraveled micronutrient deficiencies in some Nigeria Savanna soils.

In order to enhance the micronutrient status of these soils, there is need for assessment of their initial micronutrient status in order to integrate the appropriate soil fertility management that involves judicious use of combined organic and inorganic fertilizers. This is a feasible approach which has been employed in overcoming soil fertility constraints (Abedi *et al.*, 2010; Kazemeini *et al.*, 2010; Mugwe *et al.*, 2009). However, availability and uptake of micronutrients are affected by the presence of the macro-nutrients present in these amendments due to either negative or positive interactions (Fageria, 2001). Hence, caution must be taken to avoid indiscriminate use of macronutrients-borne fertilizers. The addition of organic and mineral fertilizers to soil can create a beneficial interaction between macro and micro elements, thus supplying optimum levels of needed micronutrients. This has been reported to improve crop yield and quality and play a key role in the maintenance of soil productivity (Akande *et al.*, 2006). This study was carried out to evaluate and improve upon the micronutrient status of Nigerian Guinea Savanna soil through organic and inorganic fertilizers application.

II. Materials and Methods

The study was conducted during 2010 and 2011 cropping seasons, at Bauchi, in the guinea savanna agro-ecological zone of Nigeria (10°17`N and 9°49`E). The area is characterized by two distinct seasons, the rainy season lasting from May to October and the dry season from November to April. The mean annual rainfall is 1014.70 and the mean daily maximum temperature is 26°C.

Twenty-seven surface soil samples (0 – 20 cm), were collected from a maize field laid out in a randomized complete block design (RCBD) with three replications, thus giving a total of eighty-one soil samples for laboratory analyses. Each sample was a representative of a plot. The sample collections were done three times during the study; before cropping, after the first year harvest and after the second year harvest. Two organic fertilizers: fertiplus and compost plus with NPK 20:10:10 were employed. The manures were incorporated into the plots at specified rates of 0, 5 and 10 t ha^{-1}, while NPK was applied at 0, 100 and 200 kg ha^{-1}. In the year 2010 cropping season, the organics were incorporated into the soil and left for two weeks before maize was planted. This was to allow for early microbial breakdown of the locked-up nutrients in the manures. The NPK fertilizer was incorporated in the soil three weeks after planting the maize. In the year 2011 cropping season, the experiment was repeated and done as carried out in the first year, but without application of any treatment. The collected soil samples were tested for pH, organic carbon, cation exchange capacity and available micronutrients.

The collected soil samples were air-dried and sieved through 2mm sieve. Particle size distribution was determined using the hydrometer method as described by Bouyoucos (1981). Soil pH was determined in 1:1 soil water suspension with a glass electrode pH meter. Organic carbon was determined by the wet oxidation method (Walkley and Black, 1934). Cation Exchange Capacity (CEC) was determined by sodium acetate (NaOAc) saturation and neutral ammonium acetate. The available iron, zinc, copper and manganese were determined by atomic absorption flame photometer after extracting the soil with Diethylene Triamine Penta Acetic acid (DTPA) as described by Lindsay and Norvell (1978). Data collected was subjected to Analysis of Variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for mean separation at 5% level of probability.

III. Results and Discussion

3.1 Particle Size Distribution of Soil at the Experimental Site

Table 1 showed the initial particle-size distribution as well as the micronutrient status of the soil at the experimental site. The mean values of sand, silt and clay fractions were 76.67%, 14.56% and 8.77% respectively, giving the soil a sandy clay loam texture. This suggests that the soil would be prone to leaching due to the high presence of macro-pores of the dominating sand fraction. This could adversely affect the growth of crops because of probable low water and nutrient retention capacity which aid in high leaching of soil nutrients. Furthermore, due to intense and continuous cultivation as well as the sandy nature of the soils, cations such as Ca^{2+}, Mg^{2+} and K^+ are continuously removed resulting into acidity as exhibited by the relatively low pH and CEC values of the soils of the research site. This invariably explains the reason for the observed low pH, CEC and OC status of the soil.

3.2 Initial Micronutrient Status of the Soil

The initial micronutrient status of the soil had it that Cu and Zn contents were low, while Fe and Mn contents were very high (Table 1). This means that the soil was not deficient in Fe and Mn, hence fertilizers application to raise their levels was unnecessary. The soils were sufficient in both available Fe and Mn, since their contents were more than the critical levels of 4.5 and 1 mg kg^{-1} respectively reported by Kparmwang, *et.al.* (2000) and Lindsay and Norvell (1978). The soils were all rated high (Fe > 10 and Mn > 5.0 mg kg^{-1}) for both micronutrients (Kparmwang *et. al.,* 2000). Kparmwang and Malgwi (1997); Lombin (1983); Cottenie *et. al.* (1981) and Maniyunda *et. al.* (2009) have also reported higher values of soil Fe and Mn in their study.

Several authors have indicated that the availability of micronutrients in soils depends on soil pH. Generally, micronutrients, especially Fe and Mn have been known to increase with increasing soil acidity, as observed in this study. This is similar to findings of Brady and Weil (1999), who reported that in very acid soils, there is a relative abundance of Fe and Mn. On a global study, Sillanpää (1982) reported normal to excessive levels of Mn in a number of soils from Nigeria. Findings of this study agree with that of Lombin (1983), who earlier described the sandy leached Inceptisols and Ultisols or Oxisols of the Nigerian southern savanna and derived savanna as being low in available zinc. Lombin (1983) and Pam (1990) also reported that low zinc levels in the savannah soils of Nigeria was due to low levels of the element in the parent material, absence of the micronutrient in fertilizer programme, soil pH and leaching intensities. Enwezor *et al.* (1990), reported that Cu deficiencies are common in sandy soils, and that available Fe is generally high in tropical soils. The low CEC value which also conformed with low organic carbon and high iron content of the soil, could also be attributed to the presence of highly weatherable, low activity clay probably kaolinite, which is characterized with low charge density in the soil clay fraction, thus suggesting the soil under study to be an oxisol.

3.3 Mineral Composition of the Organic Fertilizers

Table 2 presented data on the nutrients composition of Fertiplus and compost plus. Both manures were high in organic carbon, nitrogen and potassium content, but low in phosphorus content. The low phosphorus content might be due to "phosphorus problem" as reported by Holford (1997), that generally, phosphorus in all its natural forms, including organic forms is very stable or insoluble and only a small proportion exists in the soil solution at any one time.

3.4 Effects of Treatments on Selected Soil Properties and Available Micronutrients in the First and Second Year

3.4.1 Soil pH_w

Data presented in Table 3 showed that in first year, applications of fertiplus, compost plus and NPK 20:10:10 did not have significant effect (P>0.05) on soil pH. However, in the second year, only applications of the organic fertilizers increased soil pH significantly (Table 4). Applications of fertiplus and compost plus at 10 t/ha significantly reduced the soil acidity level from moderately acidic (at pH controls of 5.77 and 5.82) to slightly acidic- at pH 6.15 and pH 6.08 respectively. This was as a result of the residual effects of the organic fertilizers. This is in agreement with the findings of Jones & Wild (1975) and Ngeze (1998), that organic manures act as buffering agent against undesirable soil pH fluctuations. The delayed performance of the manures in reducing soil acidity until the second year agreed with the findings of Ramamurthy and Shivashankar (1996), that, nutrients present in organic matter are not fully available to the crops in the season of its application. Munecheru-muna *et. al*. (2007); Nnabude and Mbagwu (2001), attributed the cause to slow decomposition rate of organic fertilizers, which produces lasting residual effects on soil properties.

3.4.2 Organic Carbon

As shown in Table 3, fertiplus application at 10 t/ha increased soil organic carbon status significantly (P>0.05) to 7.87g/kg in the first year , although, there was no significant difference between fertiplus application at 5 t/ha and the control. The non-significance between their effects might be due to the uneven distribution of inherent organic carbon status across soil surface, which had complemented OC status in the control. Compost plus application also had significant effect on organic carbon with applications of 5 and 10 t/ha having significantly higher organic carbon than the control. Enhancement of organic carbon- increase in the first year could be due to the fast rate of organic matter breakdown by soil microbes in some plots under favorable soil climate. Application of NPK fertilizer did not have significant effect on organic carbon in the first year. The significantly higher values of OC gotten from the manures application over NPK application, was in agreement with findings of Melero Sanchez *et. al.* (2008), who reported that organically fertilized soils show significant increases in total organic carbon compared with those found under inorganically fertilized plots. Highest organic carbon values obtained from applications of fertiplus and compost plus in first year were 7.87 g/kg and 7.02 g/kg respectively, while they were 14.63 g/kg and 14.32 g/kg respectively in the second year. The higher value obtained from fertiplus application over compost application might be attributed to its higher organic carbon composition as presented in Table 2.

In the second year (Table 4), increasing application rates of fertiplus and compost plus increased soil organic carbon significantly (P>0.05). Applications of 5 and 10 t/ha of fertiplus raised soil organic carbon status to 12.02 and 14.63 g/kg respectively, while applications of 5 and 10 t/ha of compost plus raised organic carbon status to 11.71 g/kg and 14.32 g/kg respectively. Application of NPK fertilizer at 5 and 10 t/ha also produced significantly higher organic carbon than the control. It was observed that the increasing effect of the applied manures in the second year doubled the first year effect. This observation is in agreement with the reports of Adenawoola and Adejoro (2005) that the cumulative agronomic value of some organic manure applied to agricultural soils could be more than five times greater in the post-application period than the value realized during the year of application. The organic carbon increment observed in the second year was as a result of residual effect of the manures applied in the first year.

3.4.3 Cation Exchange Capacity

As presented in Table 3, for the first cropping season, increasing application rates of each treatment increased soil CEC significantly (P>0.05) above the control, although, not above the critical limit theorized by Esu (1991). Across all treatment levels, the highest CEC value of 5.41 cmol(+)/kg was gotten, from application of 10 t/ha of Fertiplus. Increasing rates of NPK application also increased the CEC significantly in the first year. This might be as a result of quick mineralization of the directly applied NPK fertilizer which added to the pool of soil cations, thereby enhancing their capacity for ionic exchange.

In the second year (Table 4), all the treatments rates significantly improved soil CEC above the control. Applications of 10 t/ha of fertiplus and compost plus gave CEC values of 6.62 and 6.21 cmol(+)/kg respectively, while 100 kg/ha of NPK produced 5.80 cmol(+)/kg. The soil CEC was increased above the critical limit by the residual effects of the applied organic fertilizers. The more significant effect observed from the application of these manures was due to the increase in humic substances or soil organic matter decomposition which increased negatively charged sites for soil's cation attraction and exchange, thus enhancing nutrients availability in the soil. This agrees with findings of Jones & Wild (1975) and Ngeze (1998), who reported that organic manure enhances cation exchange capacity.

3.4.4 Available Micronutrients (Zn, Cu, Fe & Mn)

In the first cropping season, effect of fertiplus on soil Zn status was not significant, while those of compost plus and NPK brought significant increase in Zn status. In the second year, application of each treatment increased Zn status significantly, with the highest increment of 0.75 mg/kg being gotten from 10 t/ha of fertiplus application. This agrees with findings of Lombin (1983); Kparmwang *et. al*. (1998); Mustapha and Singh (2003), who reported that organic matter serves as the main reservoir of plant available zinc in Nigeria savanna soils in view of the small amount of clay content. The second year increment in Zn status from the organo-minerals application was due to the residual effect of the organic fertilizers.

Soil Cu status was raised by the application of each treatment in the first year, but not up to the critical limit of 0.2 mg/kg reported by Esu (1991). In the second year, there was a steady increase in Cu status with increasing application rates of each treatment. Sole applications of 10 t/ha fertiplus, 10 t/ha compost plus and 200 kg/ha NPK raised Cu status to 0.27, 0.28 and 0.26 mg/kg respectively (Table 4). The slow increase in Zn and Cu status from first through the second year, could be attributed to the slowness of organic manures in reducing soil acidity due to their late start in nutrient release. In the case of NPK fertilizer, its application could not have been expected to have a lasting effect on the soil due to its immediate mineralization upon direct application in the first year.

In the first year, increasing application rates of NPK fertilizer increased Fe status significantly, while the organic fertilizers significantly reduced Fe status below control (Table 3). In the second year, NPK fertilizer had no significant effect on soil Fe, while increasing application rates of fertiplus and compost plus significantly reduced Fe status below the control (Table 4). The decrease in soil Fe status in the second year, was due to the increased soil pH from residual effect of the applied manures. Mckenzie (2003), reported that the availability of Fe tend to decrease as pH increases. The responsible mechanism for this, might be the formation of low solubility compounds as also reported by Akporhonor and Agbaire (2009). Through both years, the resulting Fe status was still in the high rating (Fe > 10) as reported by Kparmwang *et. al.* (2000).

None of the treatments produced significant effect on soil Mn in the first year, except 10 t/ha fertiplus application which significantly reduced Mn status below the control (Table 3). Just like the observed trend for Fe in the second year (Table 4), soil Mn was also significantly decreased by the residual effects of both organic fertilizers. The increase in the soil micronutrient status in the second year was as a result of residual effect of fertiplus and compost plus.

Table 1: Physical and chemical properties of the soil at the experimental site before the experiment

Nutrients	Values	Status*
pH (1:1$H_2$0)	5.7	Moderately acidic
Sand %	76.67	
Silt %	14.56	
Clay %	8.77	
Textural class	Sandy Clay Loam	
OC g/kg	4.62	Low
CEC cmol(+)/kg	1.6	Low
Exchangeable Cu mg kg^{-1}	0.1	Low
Exchangeable Zn mg kg^{-1}	0.18	Low
Exchangeable Fe mg kg^{-1}	22.5	High
Exchangeable Mn mg kg^{-1}	21.5	High

*Source: Esu (1991)

Table 2: Nutrient composition of Fertiplus and Compost plus (Organic Fertilizers)

Nutrient	values		
	Fertiplus	Compost plus	Percentage Difference
Organic carbon g/kg	39.64	32.50	22%
N g/kg	4.22	3.92	8%
P_2O_5 mg kg^{-1}	2.96	2.60	14%
K_2O cmol(+)/kg	2.83	1.99	42%
C/N ratio	9.4	8.3	13%

Table 3:Effects of treatment on available micronutrients of soil in 2010.

Treatment	pH_w (1:1)	Org. C. g/kg	CEC cmol(+)/kg	Zn	Cu	Fe	Mn
				←	mg/kg	→	
Fertiplus (t/ha)							
0	5.77^a	5.47^b	3.29^b	0.23^a	0.07^b	22.68^a	16.97^a
5	5.81^a	5.65^b	5.23^a	0.23^a	0.09^a	20.53^b	17.78^a
10	5.88^a	7.87^a	5.41^a	0.23^a	0.10^a	20.72^b	14.28^b
Mean	5.81	6.33	4.50	0.23	0.09	21.31	16.34
SE$\pm$	0.04	0.21	0.21	0.01	0.01	0.21	0.87
Compost Plus (t/ha)							
0	5.78^a	5.24^b	3.84^b	0.19^c	0.08^b	25.36^a	15.84^a
5	5.80^a	6.72^a	4.80^a	0.26^a	0.08^b	17.90^c	16.81^a
10	5.86^a	7.02^a	4.87^a	0.23^b	0.11^a	20.66^b	16.38^a
Mean	5.81	6.33	4.50	0.23	0.09	21.31	16.34
SE$\pm$	0.04	0.21	0.21	0.01	0.01	0.21	0.87
NPK (kg/ha)							
0	5.82^a	5.95^a	3.76^c	0.19^c	0.08^b	19.10^c	17.28^a
100	5.86^a	6.37^a	4.04^b	0.22^b	0.09^{ab}	20.73^b	16.14^a
200	5.75^a	6.67^a	4.71^a	0.28^a	0.10^a	24.09^a	15.61^a
Mean	5.81	6.33	4.50	0.23	0.09	21.31	16.34
SE$\pm$	0.04	0.21	0.21	0.01	0.01	0.21	0.87
Interaction							
F x C	*	**	**	**	ns	**	ns
F x NPK	ns	**	**	**	ns	**	ns
C x NPK	**	**	**	*	ns	*	*
F x C x NPK	**	**	**	**	*	**	*
SE$\pm$	0.04	0.21	0.21	0.01	0.01	0.21	0.87

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan Multiple Range Test, *: Significant difference at 5% level of probability, **: Significant difference at 1% level of probability, ns: Not significant at 5% level of probability.

Table 4: Effects of treatment on available micronutrients of soil in 2011.

Treatment	pH_w (1:1)	Org. C. g/kg	CEC cmol(+)/kg	Zn	Cu	Fe	Mn
				←	mg/kg	→	
Fertiplus (t/ha)							
0	5.77^b	8.78^c	4.19^c	0.29^b	0.15^c	22.53^a	34.21^a
5	6.02^a	12.02^b	5.74^b	0.30^b	0.19^b	19.12^b	31.59^c
10	6.15^a	14.63^a	6.62^a	0.75^a	0.27^a	15.97^c	32.12^b
Mean	5.98	11.81	5.52	0.45	0.20	19.20	32.64
SE$\pm$	0.08	0.12	0.12	0.03	0.00	0.74	0.19
Compost Plus (t/ha)							
0	5.82^b	9.40^c	4.82^c	0.35^b	0.14^c	20.76^a	36.39^a
5	6.04^a	11.71^b	5.54^b	0.36^b	0.19^b	19.73^a	28.42^c
10	6.08^a	14.32^a	6.21^a	0.64^a	0.28^a	17.12^b	33.11^b
Mean	5.98	11.81	5.52	0.45	0.20	19.20	32.64
SE$\pm$	0.08	0.12	0.12	0.03	0.00	0.74	0.19
NPK (kg/ha)							
0	5.96^a	10.30^b	4.88^b	0.32^c	0.17^b	18.97^a	30.84^c
100	5.92^a	12.67^a	5.80^a	0.40^b	0.17^b	19.65^a	32.24^b
200	6.05^a	12.46^a	5.59^a	0.62^a	0.26^a	18.99^a	34.84^a
Mean	5.98	11.81	5.52	0.45	0.20	19.20	32.64
SE$\pm$	0.08	0.12	0.12	0.03	0.00	0.74	0.19
Interaction							

F x C	**	**	**	**	**	**	**
F x NPK	**	**	**	**	**	**	**
C x NPK	**	**	**	**	**	**	**
F x C x NPK	**	**	**	**	**	**	**
SE+	0.08	0.12	0.12	0.03	0.00	0.74	0.19

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan Multiple Range Test, *: Significant difference at 5% level of probability, **: Significant difference at 1% level of probability, ns: Not significant at 5% level of probability.

III. Conclusion

The results obtained from this study have shown that, out of the four soil micronutrients namely, Zn, Cu, Fe, and Mn under study, only Zn and Cu were deficient while Fe and Mn were in high concentrations in the soil. On immediate basis, mineral fertilizer significantly improved soil properties except for soil pH and organic carbon. Residual effect of the applied organic matter from organic sources significantly reduced soil acidity, thus improving soil OC, CEC, Zn and Cu than did mineral fertilizer. Since iron and manganese status of the soil were already high, future deficiency in both nutrients are unlikely. There is therefore, the need to formulate organo-mineral amendments that would improve soil properties and enhance in particular, Cu and Zn availability in Nigerian savannah soils.

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