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Soil - Plant Nutrient Correlation Analysis of Maize Varieties at the Guinea Savannah

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***Abstract*—*Field trials were conducted during the rainy season of 2008 and 2009 at the Institute for Agricultural Research farm in Samaru (11^0 $11^{'}$ N, 7^0 $38^{'}$E) within the northern Guinea savanna ecological zone of Nigeria to evaluate correlation relationships among soil, yield and yield quality of maize varieties. The objectives of the study are to correlate among soil, grain yield and grain composition. The treatments consisted of four rates of nitrogen fertilizer (0, 50, 100 and 150kgNha^{-1}), two rates of micronutrients (0, cocktail mixtures) Cu, Fe, Zn, B and Mo and four maize varieties SAMMAZ 14, SUSUMA (QPM), SAMMAZ 11 and SAMMAZ 12 (normal maize) which gave a total of thirty-two (32) treatments. There was basal application of 60kgha^{-1}P and 60kgha^{-1}K. These treatments were tested in a randomized complete block design with three replications with a total of 96 plots respectively. The fertilizer treatments were factorially combined. Significant correlations were obtained between grain parameters and other yield parameters such as Stover ($r= 0.669$, $P < 0.05$); 1000grain weight ($r= 0.617$, $P < 0.05$); crude proteins ($r= 0.364$, $P< 0.05$) and total nitrogen in grain ($r =0.993$, $P < 0.05$). Grain yield also increased as soil pH ($r =0.26$, $P < 0.01$); TN ($r =0.19$, $P < 0.01$); Calcium ($r =0.17$, $P <0.05$); Zn ($r =0.24$, $P < 0.01$); Cu ($r =0.31$, $P < 0.01$) and B ($r =0.49$, $P <0.05$) increased while it decreased as crude protein (-0.39, $P<0.05$) of the grain decreased.*

Keywords*—*correlation, maize, Northern Guinea Savannah, quality protein, soil nutrient.

I. INTRODUCTION

The soil of the Northern Guinea Savanna which stretches from Latitude 7° – 12°N is characterized by the sub-humid climate covering well over 50% of the land area. The Savanna soils are highly weathered, coarse textured, low in organic matter content (2.0-10.0gkg^{-1}) and cation exchange capacity (6.0-10.0cmolkg^{-1}). They are generally acidic and poorly buffered with respect to most nutrients (Jones and Wild, 1975; Balasubramanian and Nnadi 1980; Kang and Wilson, 1987). The annual rainfall ranges from 800mm-1900 mm (Uyovbisere and Lombin, 1991). They are generally low in total nitrogen (N), values range from 0.8 to 2.9 gkg^{-1}, with a mean of 0.5 gkg^{-1}(Jones and Wild, 1975). This low value is closely linked with low organic matter content of the soils. Total phosphorus (P) is also generally low too with values ranging from 13 to 630 ppm, but a range of about 100 to 400ppm have been reported in the savannah soils (Mokwunye, 1974).

Improving nutritional quality of agricultural crops is a noble goal, which is important in cereal crops where plants have poor nutritional quality (Vassal, 2006). The nutritional well-being and health of all people are known to be vital prerequisites for the development of societies (Prasanna *et al*., 2001). Maize is gaining popularity in the Northern Guinea Savanna zone of Nigeria. In fact, it is replacing the traditional cereals, millet and sorghum (Onwueme and Sinha, 1991). Whatever the type of maize, they all require heavy fertilizer application for optimum yield (Awotundun, 2005). For mineral fertilizer, a rate of 100-150 kg N, 40-50 P_2O_5 and 80-100 kgK_2O ha^{-1}has been recommended for maize in the savanna zone (Onyinbe*et al*., 2006) while, FPDD (2002) recommended 120 kg N, 60 kg P_2O_5, and 60 kg K_2O.

Maize is progressively assuming the position as the major crop of the sub-humid and semi-arid savanna with respect to economic prospects for the farmers. It is a staple food crop in the ecological zone. A study was carried out to evaluate correlation relationships among soil, yield and yield quality of four varieties of maize in a northern Guinea savanna of Nigeria.

Objectives of the Study are:

- Evaluate relationship between the grain yield and other yield parameters.
- Correlate the soil nutrients with plant composition

II. MATERIALS AND METHODS

The field trials were carried out during the cropping season of 2008 and 2009 in Samaru, Zaria at the Northern Guinea Savanna ecological zone of Nigeria. Samaru is located at longitude 11° 11' N, latitude 7 ° 38' E at 686m above sea level. The region has an annual rainfall average of about 1060mm (Owonubi *et al*.,1991). The soil is classified as Alfisol in the USDA Soil classification system (www.nrcs.usda.gov).

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The site was divided into three blocks each, consisting 32 plots, giving a total of 96 plots and each plot measuring 12 m^2. There were 4 ridges in a plot, 3m long at 0.75m x 0.25m spacing. The experiment was laid out in a randomized complete block design with three replications and treatment was factorially combined. The maize planted were two quality protein maize (QPM) – Sammaz 14 and Susoma and two normal maize varieties – Sammaz 12 and Sammaz 11. Three maize seeds were sown in drills and thinned to one per stand. Weeding was done in each year with the use of hand-hoe.

Nitrogen was applied in 2 split doses at two weeks after planting (2WAP) and four weeks after planting (4WAP) at the rate of (0, 50, 100, 150 kg ha^{-1}) with Urea (46 %). Basal application of phosphorus and potassium were applied as 60 kg P_2O_5 ha^{-1} as single super phosphate (SSP), and 60 kg K_2O ha^{-1}potash (MOP), (60%) respectively. The cocktail micronutrient mixtures of Fe, Zn, B, Mo, and Cu were applied at the rate of 22.85gha^{-1}). The P, K, and micronutrients were all applied 2 weeks after planting immediately after thinning to one plant per stand.

Field observations were made in each plot. The response of maize varieties to the various treatments were evaluated, evaluation between grain yield and other yield parameters, grain composition and soil nutrients were studied.

Statistical Analysis

All data collected was subjected to statistical analysis using SAS statistical computer software (SAS, 2005). The correlation between grain yield, grain parameters and some soil chemical properties were established.

III. RESULTS AND DISCUSSION

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

Characterization of the soils used for the study

The soils used for the field trials were characterized for their physical and chemical properties as shown in Table 1.

Table.1: Physico-chemical properties of the soil used for the study

Parameters	Field Study (2008)	Field Study (2009)
	0-20 (cm)	0-20 (cm)
Sand (gkg^{-1})	540	530
Silt (gkg^{-1})	330	350
Clay (gkg^{-1})	130	120
Textural class	Sandy-loam	Sandy-loam
pH_{H20} 1:2.5	5.8	5.7
pH_{CaCl2} 1:2.5	5.3	5.4
Organic carbon (gkg^{-1})	5.4	5.2
Total nitrogen (gkg^{-1})	0.1	0.1
Available P ($mgkg^{-1}$)	8.9	7.6
Exchangeable acidity ($cmolkg^{-1}$)	0.4	0.6
Exchangeable bases ($cmolkg^{-1}$)		
Calcium	3.6	3.1
Magnesium	1.3	1.4
Sodium	0.5	0.4
Potassium	0.3	0.3
Effective CEC ($cmolkg^{-1}$)	5.7	5.1
Micronutrients ($mgkg^{-1}$)		
Extractable Zinc	18	10
Extractable Iron	55	52
Extractable Copper	0.6	0.6
Extractable Molybdenum	12	11
Extractable Boron	0.2	0.1

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Soil characteristics and geology

Soils of the experimental sites have been classified as Typic Haplustalf an Alfisol in the USDA Soil Classification system and it is developed in deeply weathered pre-Cambrian, basement complex rock overlain by aeolian drift materials of varying thickness (; Ogunwole, 2000). The soils were sandy loam in texture and low in clay contents (125gkg^{-1}) in the combinedfield soils respectively. Organic carbon contents of the soils were 5.4gkg^{-1} and 5.2gkg^{-1} which were low for the soils respectively. Some other workers have observed similar level of organic carbon in savanna soils, which implied low fertility status for the cultivated soil (Moberg and Esu, 1989).

The total nitrogen content of the soils is 0.1gkg^{-1}. The low level of total nitrogen in the soil could be attributed to low organic matter contents of these typical savanna soils (Jones and Wild, 1975). The available P content of the soil was moderate with values of 8.9mgkg^{-1} and 7.6mgkg^{-1} for the field soils. The exchangeable site was dominated by calcium and magnesium as characteristic of savanna soils. These cations are the most abundant in the exchange complex of savanna soils. The K saturation of field soils was 0.3%respectively. The sodium content was generally low 0.5cmolkg^{-1}and 0.4 cmolkg^{-1}as may be expected for good arable soil although Na contents were higher than K in both soils. The higher Na content in the cultivated soils relative to K must have been introduced in fertilizer materials or other amendments employed over time for crop production. The effective CEC values for the soils were 5.7 and 5.1molkg^{-1} respectively. The micronutrient values were found to be low to moderate in the soils and have been recorded to be deficient in most savanna soils (Lombin, 1985; Mulima*et al*., 2015). These soils were therefore low in natural fertility and their productivity will decline quite rapidly under continuous cultivation, which by implication requires to be fertilized in order to sustain good crop yields (Lombin, 1987).

The combined relationships between grain yield and other yield parameters were derived by simple correlation as presented in Table 2. Grain yield was significantly related with Stover yield and 1000 grain weight with r values of 0.67** and 0.62** respectively. The grain yield showed a significant but negative ($P< 0.05$) correlation with protein contents of the grain (r= -0.36**). There was a positive relationship between the grain yield and Stover yield, 1000grain- weight and plant height indicating that all these growth parameters increase or affects the grain yield of the maize. This is expected as a vigorous plant would invariably yield good harvest. The grain yield was negatively correlated with the protein contents of the grain which means the protein concentration in the grain decreased as grain yield increases. This is in accordance with Orit- Monasterio (2001) who reported same in his work. The protein content of the grain was positively influenced by the grain nitrogen. The lysine and tryptophan contents of the maize were not significantly affected by the grain yield which suggests that there was no particular pattern of relationship established between yield and quality. Lysine had a positive influence on the tryptophan content of the grain which means that increase in lysine content increases the tryptophan content of the maize.

Table.2: Correlation coefficient (r) between agronomic parameters and some grain parameters

	Grain yield	Stover yield	1000 grain weight	Plant Height	Total Nitrogen in grain	Crude protein	Lysine	Tryptophana
Grain yield	1.000							
Stover yield	0.669**	1.000						
1000 grain weight	0.617**	0.627**	1.000					
Plant Height	0.308	0.077	0.049	1.000				
Total Nitrogen in grain	-0.363**	0.017	0.004	0.032	1.000			
Crude protein	-0.364**	0.011	0.003	0.025	0.993**	1.000		
Lysine	0.083	0.027	-0.009	-0.025	0.022	0.021	1.000	
Tryptophan	-0.131	0.034	-0.095	-0.056	0.081	0.088	0.480**	1.000

** = Significant at 5%

* = Significant at 1%

The correlation matrix between grain/plant nutrients and soil parameters was shown in Table 3. The pH (r= 0.26*), soil N (r=0.19*), zinc (r=0.24*), and copper (r=0.31*) were positively correlated ($P< 0.01$) with the grain yield while the grain yield was positively and highly significantly correlated ($P< 0.05$) with boron (0.49**) and calcium (0.17**) contents of the soil respectively. Crude protein exhibited positive and significant correlation with organic carbon (r= 0.24**) content, exchangeable acidity (r= 0.14*) and pH (r= 0.02*) of the soil while it was highly significant but negatively correlated with boron (r= -0.40**), copper (r= -0.45**) and sodium (r= -0.16*) contents of the soil.

The crude protein was positively and significantly correlated with exchangeable acidity (r=0.14*), soil pH (r= 0.19*) and organic carbon (r=0.24*) and negatively correlated (P< 0.05) with sodium (r= -0.16*), boron (r= -0.40**) and copper (r= -0.45**) contents of the soil. Lysine content of the grain increased as tryptophan contents and soil N increased with r values of 0.19** and 0.07* and decreased with exchangeable acidity (r= -0.16**), sodium (-r=0.16**) and copper (r= -0.17**) contents of the soil while tryptophan increased with soil N (r= 0.15*) and decreased with exchangeable acidity (r= -0.05*) and exchangeable copper (r= -0.23**).

The pH of the soil was highly and positively correlated (P< 0.05) with exchangeable acidity (r =0.30**) and available phosphorus (r =0.30**) while it was positively correlated (P< 0.01) with exchangeable sodium (r =0.17*), extractable zinc (r=0.04*) and extractable boron (r =0.16*).

It was also correlated negatively with organic carbon (r =-0.14*) and exchangeable magnesium (r =-0.15*). The exchangeable acidity was positively correlated with available phosphorus (r =0.34**) and negatively correlated with soil N (r =-0.22*), extractable copper (-0.15*) and boron (r =-0.17*). Organic carbon content of the soil was significantly (P<0.05) and positively correlated with available phosphorus (r =0.20**) and significantly correlated (P<0.01) with exchangeable potassium (r =0.19*) but negatively correlated with extractable zinc (r =-0.20**), copper (-0.14*) and boron (r =-0.17*). Soil N was positively and significantly correlated with lysine (r =0.07*) and tryptophan content (r =0.15*) of the soil with a negative correlation with exchangeable acidity (r =-0.22*) and extractable boron (r =-0.15*) content of the soil. Available phosphorus of the soil was positively correlated with exchangeable potassium (r=0.27*) and negatively correlated with exchangeable calcium (r =-0.25*). The exchangeable calcium was highly and positively correlated with exchangeable magnesium (r =0.80**). Magnesium was highly and significantly correlated with boron (0.22**) and copper (0.14**) while zinc was positively and highly significantly correlated (P< 0.05) with boron (0.29**) and copper (0.23**) as presented on Table 3.

The grain yield increases as nitrogen content of the soil increased and soil pH was favorable to support the growth and yield of the maize since the pH of the soil was moderately acidic. Micronutrients such as zinc and boron supply from the soil also increased grain production since they are constituent of protein synthesis. This is in accordance with Osiname*et al* (1973) who reported that low zinc in the soil have been found to reduce maize yield in several parts of Africa. Anonymous (2009) inferred that Zn fertilization in maize significantly improved plant height, 100 grain weight and protein content of the maize. The grain yield was negatively correlated with exchangeable calcium. The soil pH increases with exchangeable acidity, available phosphorus and boron while it was negatively correlated with organic carbon, exchangeable magnesium and extractable zinc. The availability of zinc decreases as soil pH increased which implies that at low pH (moderately acidic), there was availability of micronutrients and macronutrients such as Zn, B, Cu, Ca and N contents in the soil and this also implies that within allowable limits for conducive crop performance, increase in soil pH, soil N, Ca, Zn, B and Cu would increase grain yield. There was a negative and significant relationship between the grain yield and the protein content of the maize in that as grain yield increases the protein content of the grain decreased. This infers that the quantity of grain produced do not determine the quality of the maize. Increased crude protein, exchangeable acidity, pH and organic carbon contents of the soil and uptake in sodium, magnesium, zinc, boron and copper contents of the soil increased the content of grain N. The crude protein content of the maize increases as the organic carbon and pH contents of the soil increased with negative correlation with Na, B and Cu. This shows that increase in uptake of these nutrients from the soil will increase the crude protein contents of the maize. Lysine and tryptophan contents of the grain maize varieties are positively affected by N, Na, Cu contents of the soil and exchangeable acidity. This infers that the amino acids increase with soil N and shows that all protein fractions in the grain are reduced when N in the soil is limiting (Pixley and Bjamason, 1993).

The increase in soil pH demonstrates a strong association with phosphorus, sodium, zinc and boron contents of the soil while availability of zinc decreases as soil pH increases. Organic carbon and magnesium contents of the soil increased as soil pH decreases. This infers that pH of the soil was favorable to support the growth and yield of the maize since the pH of the soil was moderately acid while increase in acidity of the soil increase phosphorus contents of the soil. Increase in nitrogen, boron and copper contents of the soil takes place at decrease soil acidity. Phosphorus is positively and significantly correlated with potassium and negatively correlated with calcium. This indicated that increase in phosphorus increases the potassium content and decreased the calcium content of the soil. This is called calcium induced P. K interacts with P and together they can interact with other nutrients in soil.

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Table.3: Coefficient (r) between grain yield, other yield parameters and some chemical properties of the soil

	G. yld	TNg	CP	Lys	Tryp	pH	Exacidity	OC	TNsoil	AvP	K	Na	Ca	Mg	Zn	B	Cu
G. yld	1.00																
TNg	-0.36**	1.00															
CP	-0.36**	0.99**	1.00														
Lys	-0.06	0.02	0.21	1.00													
Tryp	0.11	0.08	0.09	0.19**	1.00												
Ph	0.26*	0.20*	0.19*	-0.07	-0.08	1.00											
Exacidity	-0.11	0.14*	0.14*	-.16**	-.05*	0.30**	1.00										
OC	-0.04	0.24**	0.24**	0.02	-0.02	-0.14**	-0.16	1.00									
TNsoil	0.19*	0.05	0.07	0.07*	0.15*	-0.05	-0.22*	0.12	1.00								
AvP	0.05	0.03	0.03	0.09	-0.01	0.30**	0.34**	0.20**	-0.01	1.00							
K	-0.11	-0.05	-0.04	-0.04	0.13	-0.02	0.12	0.19*	--0.05	0.27*	1.00						
Na	0.18	-0.16*	-0.16*	-0.16**	-0.08	0.17*	-0.21	0.03	0.04	0.05	0.15*	1.00					
Ca	0.17**	0.01	0.01	-0.08	-0.00	-0.19	-0.06	-0.04	0.05	-0.25*	0.14	0.05	1.00				
Mg	0.04	-0.14*	-0.15	-0.08	-0.03	-0.15*	-0.12	-0.04	0.10	-0.24	0.10	0.03	0.80**	1.00			
Zn	0.24*	-0.38**	-0.37	0.17	0.25	0.04*	-0.04	-0.20*	0.04	-0.05	0.10	0.15	0.04	0.10	1.00		
B	0.49**	-0.41**	-0.40**	-0.02	-0.10	0.16*	-0.17*	-0.17*	-0.15*	-0.09	0.03	-0.01	0.11	0.22**	0.29**	1.00	
Cu	0.31*	-0.44**	-0.45**	-0.16*	-0.23*	0.09	-0.15*	-0.14*	-0.07	-0.10	-0.03	0.10	0.03	0.14*	0.23**	0.38	1.00

**** = Significant at 5%**

*** = Significant at 1%**

KEY G. yld–Grain yield TNg—Total nitrogen in grain CP—Crude protein Lys--Lysine Tryp—Tryptophan pH—pH soil Exacidity OC—Organic Carbon TNsoilAvP—Available phosphorus Exch K Exch Na Exch.Ca Exch Mg Extrac Zn Extrac B Extrac Cu

IV. CONCLUSION

The correlation analysis showed that all the yield parameters influenced grain yield positively and the grain yield increased as soil pH, total nitrogen, calcium, zinc, copper and boron contents of the soil increased. However, crude protein contents decreased with increase in grain yield indicating some elements of dilution of nutrients taken up as yield increased. Crude protein contents increased as totals soil N, pH, and organic carbon contents of the soil increased while lysine and tryptophan contents of the maize increased with N and K contents of the soil and was negative and significantly correlated with B and exchangeable acidity of the soil.

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