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 in Samaru (11° 11’ N, 7° 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 60kg ha⁻¹P and 60kg ha⁻¹K. 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); 1000 grain 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 (r = -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 Savannah 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 (Uyovbiere 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 (Onwume 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 P₂O₅ and 80-100 kgK₂O ha⁻¹ has been recommended for maize in the savanna zone (Onyinbeet al., 2006) while, FPDD (2002) recommended 120 kg N, 60 kg P₂O₅, and 60 kg K₂O.

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).
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$_2$O$_5$ ha$^{-1}$ as single super phosphate (SSP), and 60 kg K$_2$O 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$_{H_2O}$ 1:2.5           | 5.8                | 5.7                |
| pH$_{CaCl_2}$ 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 (cmolk$^{-1}$) | 0.4 | 0.6 |
| Exchangeable bases (cmolk$^{-1}$) |            |                    |
| Calcium                     | 3.6                | 3.1                |
| Magnesium                   | 1.3                | 1.4                |
| Sodium                      | 0.5                | 0.4                |
| Potassium                   | 0.3                | 0.3                |
| Effective CEC (cmolk$^{-1}$) | 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                |
Soils of the experimental sites have been classified asTypicHapludults and Alfisols in the USDA SoilClassification system and it is developed in deeplyweathered pre-Cambrian, basement complex rockoverlain by aeolian drift materials of varying thickness (;Ogunwole, 2000). The soils were sandy loam in textureand low in clay contents (125gkg⁻¹) in the combinedfield soils respectively. Organic carbon contents of thesoils were 5.4gkg⁻¹ and 5.2gkg⁻¹ which were low for thesoils respectively. Some other workers have observed similarlevel of organic carbon in savanna soils, which impliedlow fertility status for the cultivated soil (Moberg andEsu, 1989).

The total nitrogen content of the soils is 0.1gkg⁻¹. The lowlevel of total nitrogen in the soil could be attributed to loworganic matter contents of these typical savanna soils(Jones and Wild, 1975). The available P content of the soilwas moderate with values of 8.9mgkg⁻¹ and 7.6mgkg⁻¹ forthe field soils. The exchangeable site was dominated bycalcium and magnesium as characteristic of savanna soils.These cations are the most abundant in theexchange complex of savanna soils. The K saturation offield soils was 0.3% respectively. The sodium content wasgenerally low 0.5cmolkg⁻¹and 0.4cmolkg⁻¹as may beexpected for good arable soil although Na contents werehigher than K in both soils. The higher Na content in thecultivated soils relative to K must have been introduced infertilizer materials or other amendments employed over timefor crop production. The effective CEC values for thesoils were 5.7 and 5.1molkg⁻¹ respectively. The micronutrientvalues were found to be low to moderate inthesoils and have been recorded to be deficient in mostsavanna soils (Lombin, 1985; Mulimuet al., 2015). These soils weretherefore low in natural fertility and theirproductivity will decline quite rapidly under continuouscultivation, which by implication requires to be fertilizedin order to sustain good crop yields (Lombin, 1987).

The combined relationships between grain yield and otheryield parameters were derived by simple correlation aspresented in Table 2. Grain yield was significantly relatedwith Stover yield and 1000 grain weight with r values of0.67** and 0.62** respectively. The grain yield showedasignificant but negative (P< 0.05) correlation with proteincontents of the grain (r = -0.36**). There was a positive relationship between the grain yield and Stover yield,1000 grain-weight and plant height indicating that all thesegrowth parameters increase or affects the grain yield ofthe maize. This is expected as a vigorous plant wouldinvariably yield good harvest. The grain yield wasnegatively correlated with the protein contents of the grainwhich means the protein concentration in the graindecreased as grain yield increases. This is in accordancewith Orit-Monasterio (2001) who reported same in hiswork. The protein content of the grain was positivelyinfluenced by the grain nitrogen. The lysine and tryptophan contents of the maize were not significantlyaffected by the grain yield which suggests that there wasno particular pattern of relationship established betweenyield and quality. Lysine had a positive influence on thetryptophan content of the grain which means that increasein lysine content increases the tryptophan content of themaize.

### 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 | Tryptophan |
|----------------|-------------|--------------|-------------------|--------------|-------------------------|---------------|--------|------------|
| Grain yield    | 1.000       |              |                   |              |                         |               |        |            |
| Stover yield   | 0.669**     | 1.000        |                   |              |                         |               |        |            |
| 1000 grain weight | 0.617**     | 0.627**      | 1.000             |              |                         |               |        |            |
| Plant Height   | 0.308       |              |                   | 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       |              | -0.009            | -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 andsoil 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 yieldwhile the grain yield was positively and highlysignificantly correlated (P< 0.05) with boron (0.49**) andcalcium (0.17**) contents of the soil respectively. Crudeprotein exhibited positive and significant correlation with
The crude protein was positively and significantly correlated with exchangeable acidity (r = -0.14*), organic carbon (r = -0.24**) content of the soil and pH (r = 0.14*) 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 pH of the soil was highly and positively correlated (P< 0.05) with exchangeable acidity (r = -0.30**), available phosphorus (r = -0.30**) and while it was positively correlated (P< 0.01) with exchangeable sodium (r = -0.17*), exchangeable calcium, exchangeable magnesium and extractable zinc. It was also correlated negatively with organic carbon (r = -0.14*) and exchangeable magnesium (r = -0.15*). Organic carbon content of the soil was significantly (P<0.05) and positively correlated with available phosphorus (r = -0.34**) and negatively correlated with soil N (r = -0.22*), exchangeable copper (-0.15*) and boron (r = -0.17*). Organic carbon 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 exchangeable zinc (r = -0.20**), copper (-0.14*) and boron (r = -0.17*). Soil N was positively and significantly correlated with lysine (r = -0.17*) and tryptophan content (r = -0.15*) of the soil with a negative correlation with exchangeable acidity (r = -0.22*) and exchangeable 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 (14***) while zinc was positively and highly significantly correlated (P< 0.05) with boron (0.29**) and copper (0.23**) as presented in 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 Osumane 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 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 (Pidey 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 acidic 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.
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*| -0.16**| -0.05*| 0.30**| 1.00|     |      |      |     |     |     |     |    |    |    |
| OC    | -0.04  | 0.24**| 0.24**| 0.02 | -0.02| -0.16| 1.00|      |      |      |     |     |     |     |    |    |    |
| TNsoil| 0.19*  | 0.05  | 0.07| 0.07*| 0.15*| -0.05| 0.12| 0.19*| -0.05| 0.27*| 1.00|     |     |     |    |    |    |
| AvP   | 0.05   | 0.03  | 0.03| 0.09| -0.01| 0.40**| 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*| -0.08| -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| 0.08  |      | 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** | -0.37 | 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*| -0.15*| -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| 0.10 | 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—Exacidity  OC—Organic Carbon  TNsoil—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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