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Effects of Nitrogen and Micronutrient on Biomass Accumulation of Maize Varieties

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ABSTRACT

The experiment was conducted during the rainy seasons of 2008 and 2009 at the Institute for Agricultural Research farm in Samaru (11° 11' N, 7° 38' E), Nigeria. The study was conducted with the objectives of testing the effects of nitrogen levels and micronutrients on stover yield of maize varieties (Quality Protein Maize QPM and normal maize). The treatments consisted of four rates of nitrogen fertilizer (0, 50, 100 and 150kgNha^{-1}), two rates of micronutrients (0, cocktail mixtures of 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 with basal application of 60kgha^{-1}P as P_2O_5 and 60kgha^{-1}K as K_2O. This was tested in a Randomized Complete Block Design with three replications with a total of 96 plots respectively. The fertilizer treatments were factorially combined. The Stover yield increased as the nitrogen rate increased. The Stover yield trend was in this order: SAMMAZ 11 > SUSUMA > SAMMAZ 14 > SAMMAZ 12. Farmers can therefore adopt the QPM varieties (SUSUMA and SAMMAZ 11) since it is easy to cultivate like the normal maize in the same environment and climatic conditions with higher biomass yield.

INTRODUCTION

Crop nitrogen requirement is a physiological component which is directly related to the genetic potential of a crop and its plant growth condition (Zotarelli *et al.,* 2009). Ayub *et al.* (2002) observed that growth parameters like plant height, number of leaves per plant, stem diameter; leaf area/plant green fodder yield, dry matter yield and dry matter percentage were influenced by the application of nitrogen. El-Gizawy (2009) reported that application of nitrogen fertilizer (60-120kgN/ha) significantly increased plant height, number of grain per ear and grain yield. Nitrogen had a significant effect on plant height, number of grains per cob, 1000grain weight and harvest index (Mahmood *et al.,* 2001). Wajid *et al.* (2007) evaluated the effect of three nitrogen levels and three maize cultivars, and observed that nitrogen rates significantly affected plant height, increase in Total Dry Matter (TDM) and nitrogen accumulation.

Onasanya *et al.* (2009) in their findings reported that the application of nitrogen enhanced vegetative growth of maize as expressed by the increase observed in number of leaves, plant height, leaf area index, total dry matter per plant and relative growth rate of maize. These increases in growth parameters confirmed the importance of nitrogen as a constituent of protein and also as an integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes. Mbagwu (1990) reported that nitrogen is known to be the most important constraint to maize production in the Guinea savannah of Nigeria and that nitrogen application increased the crude protein percentage of tropical grasses. In the maize crop, nitrogen is taken up at a slower rate during development but the rate of uptake picks up rapidly by tasselling stage when about 4 kg of nitrogen is taken up per hectare per day. The rate of uptake however decreases after grain formation and by the tasselling stage, maize plants have accumulated over 40% of their total requirement during the season.

Micronutrients are absolutely essential and play an active role in gene expression, biosynthesis of protein, nucleic acids, plant metabolism processes starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation and reduction. Micronutrients are becoming increasingly important to world agriculture as crop removal of these essential element increases (Adhikary *et al*., 2010). Investigation into the micronutrient status of soils of West African savannah had received little attention in the past due to rare incidences of their deficiencies (Yaro *et al*., 2002).

In recent times, there is great demand on the land due to increase in population and the competing demand for land for non-agricultural uses which has resulted in intensive continuous cultivation in the savanna areas. With the increasing shift toward intensive continuous cultivation , the use of NPK fertilizers and improved varieties, micronutrient deficiencies are on the increase (Lombin,1983b; Kparmwang et al.,1995,1998). Increasing attention is being given to micronutrient deficiencies because increasing crop yield has led to increased uptake of micronutrients and most chemical fertilizers do not include the micronutrients. Heathcote (1973b) confirmed molybdenum while Lombin (1983a and1983b) reported that low levels of molybdenum and boron were bound to limit crop yields in the savannah. Joshy (1997) reported the critical limit of some micronutrients on maize. Trace elements which are bound up in crystal lattice of minerals are essentially unavailable to plants. Despite these numerous studies on importance of N fertilization on maize production in Nigeria, few studies assess the influence of combining nitrogen and micronutrients fertilizers in Northern Guinea savannah.

MATERIALS AND METHODS

The experiment was carried out during the 2008 and 2009 cropping seasons at Samaru, Zaria in 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 in the Northern Guinea savannah zone of Nigeria with annual rainfall average of about 1060mm (Owonubi *et al*., 1991). The soil is classified as Alfisol in the USDA Soil classification system.

The site was divided into three blocks each, consisting 32 plots, giving a total of 96 plots and each plot measuring 12m^2. There were 4 ridges in a plot, 3m long at 0.75m x 0.25m spacing on a row. 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) namely: Sammaz 14 and Susoma as well as two normal maize varieties i.e. 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 and hoe.

Nitrogen was applied in 2 split doses at 2WAP and 4WAP at the rate of (0, 50, 100, 150 kg ha^{-1}) as 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 ratio of (0, 22.85g ha^{-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 was evaluated and maize stover yield was determined at harvest.

Statistical Analysis

All data collected was subjected to statistical analysis using SAS statistical computer software (SAS, 2005). Analysis of variance was employed to determine significantly different factors. Duncan Multiple Range Test (DMRT) was used for mean separation at $p < 0.05$.

RESULTS

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). From Table 1, the soil was sandy loam in texture and low in clay contents (120gkg^{-1}). Organic carbon content of the soil was 5.00gkg^{-1} which was low for the soil. 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 soil ranged from 0.06%-0.07%, 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 value of 6.80mgkg^{-1} . The site was dominated by calcium and magnesium as characteristic of savanna soils. These cations are the most abundant in the exchange complex of savannah soils. The K saturation of the field soil was 5% respectively. Potassium fertility of the soil was in the range of0.25cmolkg^{-1}to 0.35cmolkg^{-1} with a mean of 0.35cmolkg^{-1}. The sodium content was generally low (0.30 cmolkg^{-1}) as may be expected for good arable soil although Na content was higher than K in the soil. The higher Na content in the cultivated soil 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 field top soil was 5.09 cmolkg^{-1} respectively, giving a Ca and Mg saturation of 54% and 24% respectively for the nutrients in the top soils. The micronutrient values were found to be low to moderate in the soil and have been recorded to be deficient in most savanna soils . This soil was 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).

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

Parameters	Field Study	
	0-15 (cm)	15-30 (cm)
Sand (gkg^{-1})	530.0	525.0
Silt (gkg^{-1})	350.0	350.0
Clay (gkg^{-1})	120.0	125.0
Textural class	Sandy-loam	Sandy-loam
pH_{H20} 1:2.5	5.70	5.60
pH_{CaCl2} 1:2.5	5.40	5.20
Organic carbon (gkg^{-1})	5.20	5.00
Total nitrogen (%)	0.06	0.07
Available P (mgkg^{-1})	7.58	6.80
Exchangeable acidity (cmolkg^{-1})	0.60	0.52
Exchangeable bases (cmolkg^{-1})		
Calcium	3.08	3.00
Magnesium	1.36	1.29
Sodium	0.40	0.30
Potassium	0.25	0.35
Effective CEC (cmolkg^{-1})	5.09	4.94
Micronutrients (mgkg^{-1})		
Extractable Zinc	10.75	12.40
Extractable Iron	52.00	45.50
Extractable Copper	0.58	0.55
Extractable Molybdenum	11.00	11.08
Extractable Boron	0.10	0.11

Main Effect of Nitrogen Fertilizer on Maize Stover Yield

The Stover yields for the two years 2008 and 2009 and when combined were significant at ($P < 0.05$) and it increased as nitrogen rates increased (Table 2). SAMMAZ 11 (normal maize) performed best with the yield of 4.25tha^{-1} followed by SUSUMA with 4.05tha^{-1}, SAMMAZ 14 produced Stover yield of 3.99tha^{-1} and SAMMAZ 12 had the yield of 3.6tha^{-1} respectively.

The contrast between the quality protein maize and the normal maize was highly significant at ($P < 0.05$) and also between the QPM_A and QPM_B as seen in Table 2.

Table 2: Main Effect of Nitrogen on Maize Stover Yield

		Stover yield (kgha^{-1})		
Variety	Nitrogen (kgha^{-1})	2008	2009	Combined
SAMMAZ 14	0	1684.62	2486.02	2085.32
	50	3138.63	3166.54	3152.58
	100	4347.08	3638.74	3867.92
	150	4152.47	3416.53	3895.61
Mean		3330.70	3176.96	3243.61
SUSUMA				
	0	833.35	2611.01	1722.18
	50	1854.00	3222.09	2531.15
	100	2458.24	3277.65	2867.95
	150	3569.29	4527.59	4048.44
Mean		2178.72	3409.59	2792.43
SAMMAZ 12	0	2479.09	1638.82	2058.95
	50	2923.49	2138.81	2531.15
	100	3665.06	2055.47	2860.26
	150	4555.37	2708.23	3631.80
Mean		3405.75	2135.33	2770.54
SAMMAZ 11	0	2326.29	3166.55	2746.42
	50	2879.05	3860.95	3370.00
	100	3944.29	3555.41	3749.85
	150	4645.65	3860.96	4253.31
Mean		3448.82	3610.97	3529.89
Mean		3090.99	3057.51	3070.56
SE ±		488.35	194.66	211.53
CV (%)		38.69	25.47	35.34
V x N		NS	NS	NS
CONTRAST				
QPM vs Normal		**	**	**
QPM_A vs QPM_B		**	**	**
With vs Without M/nut		NS	NS	NS

Effect of micronutrients on Stover yield of maize

Micronutrient applications enhanced the yield of maize Stover in that the quality protein maize, SAMMAZ 14 and SUSUMA had the Stover yield of 3.37tha^{-1} and 2.82tha^{-1} with added micronutrients (Table 3). SAMMAZ 11, normal maize produced the highest Stover yield of 3.71ha^{-1} also with added micronutrients while SAMMAZ 12 produced a yield of 2.86tha^{-1} without micronutrients application as seen in Table 3.

Table 3: Effects of Micronutrients on maize Stover yield

		Stover yield (kg ha^{-1})		
Variety	Micronutrients	2008	2009	Combined
SAMMAZ 14	-M	3013.77	3281.07	3147.42
	+M	3367.92	3380.33	3374.13
SUSUMA	-M	3402.64	2135.35	2768.99
	+M	3416.53	2222.09	2819.31
SAMMAZ 12	-M	2201.30	3510.27	2855.79
	+M	2069.36	3301.23	2685.29
SAMMAZ 11	-M	3513.75	3192.93	3353.34
	+M	3708.19	3704.71	3706.45
Mean		3086.68	3090.99	3070.56
SE±		213.68	345.32	313.29
CV (%)		23.98	38.69	35.34

Interactive effects of treatments on Stover yield of the maize genotypes

When the two years were combined the highest Stover yield was 4.21tha^{-1} at 150kgNha^{-1} with micronutrients by SAMMAZ 14 (Table 4). SUSUMA produced Stover yield of 4.39tha^{-1} at the highest level of N applied with micronutrients as seen for both years. SAMMAZ 11 recorded the highest yield of 3.72tha^{-1} with applied micronutrients the yield was not statistically different from the yield of SAMMAZ 12 which was 3.74tha^{-1}. Comparing the varieties, the quality protein maize performed significantly better than the normal maize and there was significant difference between the QPM_A and $QPM_{B.}$

Table 4: Interaction between Effects of Treatments on Maize Genotypes Stover yield

	Micronutrient (gha^{-1})					
	2008		2009		Combined	
Variety x N level (kg Nha^{1})	-M	+M	-M	+M	-M	+M
SAMMAZ 14 (QPM)						
0	2388.0	2358.0	1847.2	1522.1	2151.3	2052.6
50	2999.9	3333.0	2582.9	3694.3	2791.4	3513.7
100	3277.7	3667.5	3777.6	4916.6	4097.1	3722.6
150	3388.8	3888.7	3877.6	4527.3	3583.2	4208.0
Mean	3013.8	3368.1	3281.1	3380.3	3155.8	3374.2
SUSUMA (QPM)						
0	2833.2	2389.8	916.7	749.9	1840.0	1569.9
50	2944.3	3499.9	1916.3	1791.7	2430.3	2645.8
100	3555.4	2999.9	2916.6	1999.9	3236.0	2499.9
150	4277.6	4777.6	3138.8	3999.8	3708.2	4388.7
Mean	3416.8	3402.6	2222.1	2135.3	2803.6	2776.1
SAMMAZ 12						
0	1666.6	1611.1	2805.4	2152.7	2236.0	1881.9
50	1999.9	2277.7	2624.9	3222.1	2312.4	2749.9
100	1888.8	2222.1	3024.8	4305.4	2456.8	3263.8
150	2722.1	2694.3	4749.8	4360.9	3735.9	3527.6
Mean	2069.4	2201.3	3301.2	3510.3	2685.3	2855.8
SAMMAZ 11						
0	3444.3	3458.2	3458.2	1194.4	2326.3	3451.3
50	3888.7	2091.6	2091.6	3666.5	2879.1	2990.2
100	3777.6	3499.9	3499.9	4388.7	3638.8	3638.8
150	3722.1	3722.1	3722.1	5569.2	3520.1	3722.1
Mean	3708.2	3192.9	3192.9	3704.7	3448.8	3450.6
Mean	3044.3	3122.9	3110.9	3004.0	3077.7	3063.5
SE ±	224.25	264.97	159.43	154.48	217.50	207.14
CV (%)	36.0	41.57	25.11	25.19	34.62	36.23
V x N	NS	NS	NS	NS	NS	NS
CONTRAST						
QPM vs Normal	**	**	NS	**	NS	**
QPM_A vs QPM_B	NS	NS	NS	NS	*	*

DISCUSSION

Physico-Chemical Characteristics of the Soils of the Experimental Site

The pH of the soil measured in water (H_2O) indicated moderate to mild acidity. This is typical of savanna soils with pH range of 4-6.5 (Jones and Wild, 1975). The pH value in water was 5.80 indicating that exchangeable aluminum toxicity may not be a problem in these soil (Dauda, 2004).

The low level of organic carbon content and organic matter in the soil of the experimental site was probably as a result of high proportion of sand content of the soil. Jones and Wild (1975) reported that organic matter content decreased latitudinal from the south to the north as the amount of rainfall received and vegetation cover decreases. Low organic carbon is attributed to inadequate supply of organic litter, bush burning, long dry season and intensive mineralization during the raining season (Dugje *et al*., 2008). The low level of organic carbon coupled with the sandy texture associated with the soil would normally encourage a rapid leaching of cations (Jones, 1973, Enwezor *et al.,* 1989) and consequently the soil would be low in CEC.

The total nitrogen content of the soil was low. This low value was closely linked with low organic content of the soil which is typical of tropical savanna soil (Jones and Wild, 1975). Furthermore, the low N levels observed in the soil can be attributed to continuous cropping and increased land use intensity. Manyong *et al*. (1996) caution that soil depletion would be a serious problem in areas where land used intensification was on the increase. The low available P agrees with the report of Jones and Wild (1975) and Dugje *et al*. (2008), that P is one of the limiting nutrients to crop production in the northern savanna of Nigeria. This can be attributed to the low OM contents of these typical savannah soils. These levels were consistent with what was observed in the soils of the northern Guinea savannah (Lombin *et al.,* 1985; Uyovbisere and Lombin, 1991). The site was high in calcium and magnesium as characteristic of savanna soils. These cations are the most abundant in the exchange complex of savannah soils. The potassium fertility of the soil was rated medium to high with a mean of 0.64cmolkg^{-1}. The average range of soil K values for the Nigeria savanna soils is 0.5 – 0.25cmolkg^{-1} and this is rated as medium while value greater than 0.3 cmolkg^{-1} are regarded as high (Jones and Wild, 1975). The sodium content was generally low as may be expected for good arable soil. The ECEC values were low for field soil.

The micronutrient values were found to be low to moderate in the soils. These soils are 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).

There was an increase in the Stover yield as nitrogen rates increased from the control to the highest rate of N (150kgNha^{-1}). This is in accordance with Tanimu *et al,* (2007), who recorded an increase in Stover yield as nitrogen rates increased in an experiment in Samaru. Daudu (2004) also observed an increase in the Stover yield of maize in Samaru with increasing nitrogen rates 0-120kg Nha^{-1}. This increase showed that increase in nitrogen rates increased the dry matter yield. Onasanya *et al.*(2009) in their findings reported that application of nitrogen enhanced vegetative growth of maize as expressed by the increase observed in number of leaves, plant height, leave area index, total dry matter per plant and relative growth rate of maize.

The contrast analysis between the quality protein maize and the normal maize and also between the QPM_A and QPM_B was highly significant indicating that the varieties differ in their utilization of nitrogen fertilizers. When the Stover yield were combined for both years, it showed that the QPM (SAMMAZ 14 and SUSUMA) responded to micronutrients addition in that the micronutrients enhanced maize growth performance which was an indication that QPM varieties have the capacity to utilize high levels of micronutrient for the synthesis of the biomass than the normal maize. This indicated that nitrogen application had pronounced effect in increasing vegetative growth of crop plants.

Micronutrients application enhanced the Stover yield of SAMMAZ 14 and SUSUMA varieties. SAMMAZ 14, SUSUMA and SAMMAZ 11 conventional maize responded to micronutrient fertilizers. This implied that SAMMAZ 14, SUSUMA and SAMMAZ 11 varieties were more vigorous and efficient in the utilization of applied micronutrients while SAMMAZ 12 did not respond to micronutrients application.

CONCLUSION

The biomass increased as the nitrogen rate increased, this indicated that nitrogen application had pronounced effect in increasing vegetative growth of Maize. The Stover yield trend was in this order: SAMMAZ 11 > SUSUMA > SAMMAZ 14 > SAMMAZ 12. Also the micronutrients enhanced maize growth performance which was an indication that QPM varieties have the capacity to utilize high levels of micronutrient for the synthesis of the biomass than the normal maize.

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