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EFFECTS OF NITROGEN AND SULFUR ON LEAF AREA INDEX AND TOTAL DRY MATTER OF QUALITY PROTEIN MAIZE AT SAMARU ZARIA

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ABSTRACT
Field trial was conducted in 2006, and repeated in 2007 and 2008 wet seasons, at the Institute for Agricultural Research Farm, Samaru in the northern Guinea Savanna of Nigeria to determine the effects of nitrogen and sulfur fertilizer rates on two quality protein maize (QPM) varieties. Treatments consisted of four (4) rates each of nitrogen (0, 60,120 and 180 kg N/ha) and sulfur (0, 5, 10 and 15 kg S/ha) fertilizers and two QPM varieties (Obatanpa and EV – 99), laid out in a split plot design with combinations of variety and nitrogen in the main plots, sulfur in the sub plots and replicated three times. The results showed that the application of 120 kg N/ha produced significantly higher leaf area index, while further increase to 180 kg N/ha did not affect the parameter. Similar but significantly heavier total dry matter (TDM) was produced by all the three N rates compared to the control. The application of sulfur did not significantly influenced these parameters except TDM at 8 WAS in 2007, where 0 kg S/ha produced lower TDM though statistically similar to 5 kg S/ha. The two varieties did not differ in leaf area index but TDM was heavier with EV-99 than Obatanpa. Varieties did not differ in their grain yield. Nitrogen application significantly increased grain yield up to 120 kg N/ha, but further increase to 180 kg N/ha did not make any significant change. Sulfur only influenced grain yield/ha in 2008 with 10 kg S/ha producing higher grain yield/ha than the other rates. Highest grain yield was observed from the interaction between 60 kg N/ha and 10 kg S/ha, while the lowest grain yield was produced by the combination of 120 kg N/ha and 0 kg S/ha.

KEY WORDS: Nitrogen, Sulfur, quality protein maize and Varieties

INTRODUCTION

Maize *(Zea mays* L.) is a member of the grass family, *Gramineae*, to which all the major cereals belong. Modern maize probably evolved from wild maize in the Americas and thus it is not a product of hybridization of other species (Mangeldort, 1965). The oldest evidence of domesticated maize came from archaeological sites in Mexico where small cobs estimated to be 7,000 years old have been found in caves. From its center of origin in Mexico and Central America, maize migrated to the rest of Latin America, the Caribbean and the United States and Canada (Dowswell et *aI*., 1996). Maize is one of the most important food crops worldwide, grown between latitude 58^o N and 49^0 S of the equator. Varying latitudes have an effect on number of days to flowering and maturity. This is as a result of higher temperatures at lower altitudes, which accelerate growth while the lower prevailing temperatures at higher altitudes retard growth and extend time to maturity (Seed Co., 1999). Maize is the most important cereal in the United States occupying double the area of all others crops. Some parts of Africa particularly South Africa, Malawi, Zimbabwe, Kenya, Tanzania, Ghana, Nigeria and Egypt have eco-typic environments favourable for maize production. Maize is fast replacing traditional staple foodstuffs such as Sorghum (*Sorghum bicolor* L.*)* and Millet (*Pennisetum glaucum* L.*)*. Quality protein maize is more nutritious than conventional maize. This is due to the fact that its amino acid profile contains two amino acids namely lysine and tryptophan in their endosperm which are lacking in the amino acid profile of conventional maize. (Paiva *et al*., 1991). Most Nigeria diets are cereal based with low protein intakes. The inclusion of QPM with its high lysine and tryptophan content will alleviate some of the deficiencies of the dietary protein. The two varieties of QPM used for this study namely Obatanpa and EV-99 were the most popular varieties in the study area, which have reached the farmers; hence their choice for the study. Nitrogen is a major plant nutrient for growth and makes up 1 to 4 percent of dry matter of plants (Anon. 2000). It is a component of protein and nucleic acids and when N is sub-optimal; growth is reduced (Hague *et al*., 2001). Nitrogen is the most limiting nutrient in the savanna soils where the soils are predominantly coarse textured and characteristically low in organic matter. Its deficiency is usually recognized first by pale green or yellowish green colour of the leaves, followed by premature necrosis of the older leaves. Where soils are rich in organic matter, such as where the land has just been cleared after a long fallow, a fair amount of nitrogen would be made available to crops through the decomposition of the organic matter (Anon., 1989). Based on the importance of nitrogen as mentioned above, it was chosen as one of the factors of the treatment. Sulfur is the fourth major nutrient after N, P and K. It is a constituent of the essential amino acids lysine and tryptophan. On the average maize crop absorbs as much S as it absorbs P. When S is deficient in soil, full yield potential of the crop cannot be realized regardless of other nutrients even under good crop husbandry practices (Tandon, 1989). Deficiency of S is likely to be widespread in Africa, especially in the savanna regions, where annual bush burning results in losses of sulfur to the atmosphere as Sulfur dioxide (SO_2) (Tandon, 1989). The investigation was therefore, aimed at evaluating the effects of nitrogen and sulfur on quality protein maize (QPM) varieties with respect to growth and yield performance.

MATERIALS & METHODS

The experiment to evaluate response of two quality protein maize varieties to different rates of nitrogen and sulfur was conducted for three years during the wet season of 2006, 2007 and 2008 at Samaru, Zaria (11^0 $11^/$ N; 07^0 $38^/$ E and 686 meters above sea level), located in the northern Guinea Savanna zone of Nigeria. The experiment was laid out in split plot design with nitrogen and maize variety in the main plot and sulfur in the subplot. The treatments consisted of two open pollinated QPM varieties (Obatanpa and EV – 99), four rates each of nitrogen (0, 60, 120 and 180 kg N/ha) using urea (46%N) and sulfur (0, 5, 10, and 15 kg S/ha) using potassium sulfate (1%S) to evaluate effects of nitrogen and sulfur on quality protein maize (QPM) varieties with respect to growth and yield performance. The experiment was replicated three times. Soils were randomly sampled from the experimental site before land preparation each year, at the depth of 0 – 30 cm and a composite sample was taken, dried, ground and sieved using 1mm sieve. The composite sample in each year was taken to laboratory and analyzed for the determination of physical and chemical properties. The land was double harrowed and then ridged 75cm apart. Plots were demarcated after ridging with well-formed borders between plots (1m) and replications (1.5m) to minimize nutrient seepage. Sowing was done by hand after a good rain to provide moisture for good germination. Two seeds were planted per hole at the spacing of 25cm between stands, and the seedlings were later thinned to one plant per stand at two weeks after sowing. The nutrients applied were N, P, K and S where by P, K, S and 75% of N were applied at 3 weeks after sowing while the remaining 25% of N at 6 weeks after sowing. P and K were equally applied to all plots at the rate of 26 and 50 kg/ha respectively, while N and S were varied according to the rates used for the trial (0, 60, 120 and 180 kg N ha^{-1} and 0, 5, 10 and 15 kg S ha^{-1}). Weeding was done manually using hoe to control weeds at 3 and 6 weeks after sowing. Second weeding was followed by second dose of N fertilizer application and remoulding to cover the applied N and give support to the crop against lodging. Five plants were tagged in each plot for the measurement of growth parameters, while yield was measured from the net plots. Leaf area index and total dry matter were assessed at 4, 8 and 12 weeks after sowing (WAS). The length and maximum width of each leaf for the five tagged plants were measured using a metre rule. Values obtained were multiplied to get leaf area for each leaf. The leaf area for each leaf was then multiplied by a factor 0.75 (crop factor) developed by Duncan and Hesketh (1968). Products of the multiplication for each leaf were summed up and then divided by land area occupied by the plants to give leaf area index (LAI) (Duncan and Hesketh, 1968). Total dry matter in grams was determined by sampling five plants per plot (outside the net plot) for oven drying to a constant weight and the average was recorded as total dry matter weight per plant in grams. Grain yield per net plot was weighed and the value was converted to per hectare basis. Data collected were subjected to statistical analysis of variance and means of treatments were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955).

RESULTS

Table 1 shows physical and chemical properties of the soils of the experimental site. Physical characteristics of the soil in 2006 and 2008 were loam, while that of 2007 was sandy loam. Chemical characteristics of the soils of the trial fields indicated pH ranging from strongly acidic to moderately acidic (5.15 - 6.44). Organic carbon was low in 2007 and 2008 with value of 0.59 and 0.90% respectively, whereas in 2006 it was better with moderate value of 1.44%. Total nitrogen was low in 2007, medium in 2008 and high in 2006 with values of 0.11, 0.18 and 0.27% respectively. Available Phosphorus (mg/kg) ranged from moderate in 2007 to high in 2006 and 2008 with values of 7.35, 22.40 and 23.45 respectively. Exchangeable bases (Cmol/kg) were generally observed to be in the range of low to moderate level in the soils of the experimental sites. Cation exchange capacity (CEC) of the soil of the experimental fields was observed to be generally moderate ranging between 6 to 8 Cmol/kg. Varieties did not differ in their leaf area index (LAI) (Table 2). Nitrogen influenced leaf area index in 2006, 2007 and when averaged over years at 8 and 12 WAS. Nitrogen rates at 180 kg N/ha produced significantly higher LAI than the other rates which were statistically similar in 2006, 2007 and when averaged over years at 8 WAS though at par with 120 kg N/ha in 2006. However, significantly higher LAI was produced at 12 WAS with application of 120 kg N/ha in 2006 and when averaged over years than the other rates which were statistically similar but only when averaged over years. While in 2007 at 12 WAS 0 kg N/ha produced significantly lower LAI than the other rates which were statistically similar. Significantly different TDM was observed between the varieties at 4 WAS in 2007 and 4, 8, and 12 WAS in 2008 (Table 3). EV – 99 yielded higher dry matter than Obatanpa at all the sampling period and years. Application of nitrogen influenced TDM at 8 and 12 WAS in all the three years and when averaged over years, except 2006 at 8 WAS. All the applied nitrogen rates produced statistically similar TDM but significantly higher than 0 kg N/ha. Sulfur only influenced TDM significantly in 2007 at 8 WAS, when 0 kg S/ha produced lower TDM than all the other sulfur rates but only significant with 10 and 15 kg S/ha.

TABLE 1: Physical and chemical properties of the soils of the experimental sites at Samaru Zaria in 2006, 2007 and 2008.

Soil Characteristics	Soil Depth (0 – 30cm)		
	2006	2007	2008
Physical Characteristics (%)			
Sand	36.40	51.40	31.40
Silt	50.00	37.50	50.00
Clay	13.60	11.10	18.60
Textural Class	Loam	Sandy Loam	Loam
Chemical Characteristics			
pH 1:2.5 in H_2O	5.91	6.44	6.01
pH 1:2.5 in $CaCl_2$	5.69	5.15	5.28
Organic Carbon (%)	1.44	0.59	0.90
Total Nitrogen (%)	0.27	0.11	0.18
Available Phosphorus (mg/kg)	22.40	7.35	23.45
Exchangeable Bases (Cmol/kg)			
Ca	4.80	3.00	3.60
Mg	3.00	1.80	3.00
K	0.28	0.41	0.33
Na	0.61	0.87	0.83
S	5.50	7.50	8.00
CEC	8.69	6.08	7.76
ECEC	9.29	6.18	8.16
Total Acidity	0.60	0.10	0.20

Interaction between N and S was significant at 12 WAS in 2006 (Table 4). Highest TDM was produced by the combination of 120 kg N/ha and 5 kg S/ha, while the lowest by the combination of 0 kg N/ha and 0 kg S/ha. Grain yield response to N and S is presented in Table 5. Varieties did not show any significant difference in the three years and when averaged over years. Nitrogen application significantly influenced grain yield/ha in all the three years and when averaged over the years, with increase in grain yield up to 120 kg N/ha, but further increase to 180 kg N/ha did not make any significant change. Sulfur only influenced grain yield/ha in 2008 with 10 kg S/ha producing higher grain yield/ha than the other rates though at par with 5 kg S/ha. Interaction between nitrogen and sulfur significantly influenced grain yield/ha in 2006 (Table 6). Highest grain yield was observed from the interaction between 60 kg N/ha and 10 kg S/ha, though at par with the combination of 0, 5, 10 kg S/ha and 120, 180 kg N/ha and also 15 kg S/ha combined with 60 kg N/ha. While the lowest grain yield was produced by the combination of 120 kg N/ha and 0 kg S/ha.

DISCUSSION

The two varieties gave similar leaf area index and grain yield but differ in total dry matter. This response could be due to the fact that the two varieties were similar in terms of net assimilation rate which is an important factor in the production of assimilate for subsequent translocation to the other organs. A report by (Sallah *et al*., 2003) showed Obatanpa to have similar scores with currently released varieties for most yield components. Mani (2009) also reported that when five QPM varieties were evaluated the result showed similarity in some QPM varieties. Akande and Lamidi, (2006) also reported insignificant difference in grain production between QPM varieties. Application of nitrogen significantly enhanced leaf area index, total dry matter and grain yield. This was expected because N is one of the nutrients needed by plants more than other nutrients and also required for a wide range of growth processes (Yara, 2009). Moreover the soils of the experimental area were low in N and so the response was expected. Maize responds to N on low N soil. This could be due to the positive influence of nitrogen associated with its role in promoting rapid vegetative growth and its direct effect on cell division, elongation and expansion and synthesis of enzymes and chlorophyll (Brady and Weil, 2004; John *et. al*., 2006). A report by Haque *et al*. (2001) showed that nitrogen is a component of protein and nucleic acids and when N is sub-optimal, growth is reduced. The effect of nitrogen on leaf area index (LAI) could also be attributed to increase in leaf size. Since nitrogen is involved in the synthesis of chlorophyll molecules, its application increases the crop's ability to intercept more solar energy for increased CO_2 assimilation. This finding corroborates with that of Aliyu *et.al*. (1996) who reported that excessive nitrogen reduces yield and yield components by extending plant vegetative growth period. Application of sulfur did not significantly influence growth parameters. Yield parameters such as grain weight per plant and grain yield/ha were influenced by sulfur application in 2008 with 10 and 15 kg S/ha producing similar but higher value than 0 and 5 kg S/ha. This observation could be attributed to the fact that the soil of the trial area contains moderate amount of sulfur, hence addition of sulfur had insignificant effect on growth and development parameters. This observation contradicts the report by Ray and Mughogho, (2000) and Muhammad *et. al*., (2004) who reported that S application significantly increased dry weight per plant at tasselling when sulfur was applied from 0 to 30 kg S/ha.

TABLE 2: Effects of nitrogen and sulfur fertilizers on leaf area index of two quality protein maize varieties at 4, 8, and 12 WAS in three years and the mean.

	Leaf Area Index											
	4WAS				**8WAS**				**12WAS**			
Treatment	2006	2007	2008	Mean	2006	2007	2008	Mean	2006	2007	2008	Mean
QPM Variety												
Obatanpa	0.162	0.203	0.145	0.170	0.78	1.04	1.12	0.98	1.01	1.04	1.31	1.12
EV-99	0.162	0.216	0.153	0.177	0.78	1.01	1.15	0.98	0.94	0.94	1.31	1.06
S.E. ±	0.008	0.008	0.008	0.005	0.02	0.04	0.04	0.02	0.03	0.06	0.03	0.02
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen Fertilizer (kg N/ha)												
0	0.155	0.194	0.135	0.172	0.73 b	0.93 b	1.09	0.95 b	0.85 c	0.76 b	1.24	0.99 b
60	0.158	0.209	0.145	0.172	0.74 b	0.97 b	1.13	0.95 b	0.89 c	1.06 a	1.28	1.07 b
120	0.162	0.214	0.155	0.174	0.78ab	1.01 b	1.15	0.96 b	1.14 a	1.08 a	1.35	1.19 a
180	0.172	0.222	0.162	0.176	0.85a	1.19 a	1.18	1.06 a	1.04 b	1.07a	1.38	1.13 b
S.E. ±	0.011	0.011	0.011	0.007	0.03	0.06	0.06	0.03	0.035	0.079	0.042	0.032
Significance	NS	NS	NS	NS	*	*	NS	*	**	*	NS	**
Sulfur Fertilizer (kg S/ha)												
0	0.169	0.234	0.149	0.184	0.79	1.04	1.16	1.00	1.04	1.00	1.34	1.13
5	0.164	0.202	0.152	0.173	0.79	1.01	1.14	0.98	0.95	0.951	1.29	1.06
10	0.161	0.198	0.146	0.168	0.78	1.03	1.13	0.98	0.95	1.02	1.31	1.09
15	0.153	0.205	0.150	0.169	0.74	1.02	1.12	0.96	0.97	0.99	1.31	1.09
S.E. ±	0.007	0.011	0.007	0.005	0.03	0.03	0.04	0.02	0.035	0.032	0.03	0.020
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
VxN	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VxS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
NxS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a year and treatment group are not significantly different at 5 percent level of probability according to DMRT.
NS = Not Significant ** = Significant at 1% level of Significance * = Significant at 5% level of Significance

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TABLE 3: Effects of nitrogen and sulfur fertilizers on total dry matter of two quality protein maize varieties at 4, 8, and 12 WAS in three years and the mean.

	Total Dry Matter (g/plant)											
	4WAS				8WAS				12WAS			
Treatment	2006	2007	2008	Mean	2006	2007	2008	Mean	2006	2007	2008	Mean
QPM Variety												
Obatanpa	11.7	9.9 b	8.7 b	10.1	76.8	118.7	107.4 b	101.0	305.0	459.2	446.0 b	403.4
EV-99	10.4	11.0a	10.6 a	10.7	70.4	109.0	125.6 a	101.6	296.0	469.7	506.3 a	424.0
S.E. ±	0.6	0.3	0.4	0.3	6.4	7.2	3.6	3.4	11.5	27.3	11.4	10.6
Significance	NS	*	**	NS	NS	NS	**	NS	NS	NS	**	NS
Nitrogen Fertilizer (kg N/ha)												
0	10.5	11.0 c	9.3	10.0	57.5	74.3 b	98.0 b	76.6 b	239.8 b	338.5 b	422.3 b	333.5 b
60	11.0	10.1 bc	9.5	10.4	80.6	119.7 a	117.3 a	106.8 a	328.9 a	520.3 a	475.8 a	444.9 a
120	12.0	11.0 ab	10.4	10.8	83.3	129.2 a	125.4 a	111.7 a	329.3 a	530.1 a	501.1 a	450.2 a
180	10.9	11.28 a	9.4	10.4	73.0	132.2 a	125.3 a	110.1 a	304.1 a	469.1 a	505.4 a	426.2 a
S.E. ±	0.9	0.4	0.6	0.4	9.0	10.2	5.1	4.9	16.2	38.6	16.1	15.0
Significance	NS	*	NS	NS	NS	**	**	**	**	*	**	**
Sulfur Fertilizer (kg S/ha)												
0	11.5	11.1	9.3	10.6	68.4	103.5 b	112.7	99.3	295.1	427.9	436.4	395.1
5	11.0	10.5	11.0	10.8	71.7	114.3 ab	114.7	100.2	286.6	453.8	475.1	414.8
10	11.3	9.1	9.6	10.0	76.2	116.7 a	117.3	100.3	317.6	467.2	494.1	415.0
15	10.6	11.2	8.7	10.2	78.1	120.9 a	121.2	105.4	302.7	509.0	498.9	429.9
S.E. ±	0.5	0.6	0.6	0.4	5.8	4.0	6.3	3.2	9.0	21.0	21.9	10.7
Significance	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Interaction												
VxN	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VxS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
NxS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

Means followed by the same letter(s) within a year and treatment group are not significantly different at 5 percent level of probability according to DMRT.
NS = Not Significant ** = Significant at 1% level of Significance * = Significant at 5% level of Significance

TABLE 4: Interaction between nitrogen and sulfur fertilizer rates on total dry matter (g/plant) of QPM varieties at 12 WAS in 2006 wet season

Treatment	Nitrogen Rates (kg/ha)			
Sulfur Rates (kg/ha)	0	60	120	180
0	219.0 e	288.7 bcd	339.6 abc	333.0 abc
5	220.7 e	314.1 abc	309.4 abc	302.3 bc
10	281.7 cd	367.8 a	319.4 abc	301.5 bc
15	237.7 de	346.5 ab	347.3 ab	279.5 cd
S.E.±	18.03			

Means followed by the same letter(s) are not significantly different at 5 percent level of probability according to DMRT.

TABLE 5: Effects of nitrogen and sulfur fertilizers on grain yield (kg/ha) of two quality protein maize varieties in three years and the mean

	Grain Yield (kg/ha)			
Treatment	2006	2007	2008	Mean
QPM Variety				
Obatanpa	3602.4	1980.0	5087.7	3556.7
EV-99	3559.2	2040.7	4934.7	3511.5
S.E. ±	118.10	76.10	106.75	58.82
Significance	NS	NS	NS	NS
Nitrogen Fertilizer (kg N/ha)				
0	1897.4 c	830.85 c	3217.0 c	1981.8 c
60	3774.0 b	2160.9 b	5101.3 b	3678.7 b
120	4505.1 a	2609.3 a	5711.9 a	4275.4 a
180	4146.8 ab	2440.3 ab	6014.6 a	4200.5 a
S.E. ±	167.02	107.61	150.97	83.18
Significance	* *	**	**	**
Sulfur Fertilizer (kg S/ha)				
0	3688.8	2120.3	4867.8 b	3559.0
5	3497.4	2209.0	4983.2 ab	3563.2
10	3474.7	1776.0	5399.9 a	3550.2
15	3662.5	1936.0	4793.8 b	3464.1
S.E. ±	106.22	121.54	157.97	79.49
Significance	NS	NS	*	NS
Interaction				
VxN	NS	NS	NS	NS
VxS	NS	NS	NS	NS
NxS	**	NS	NS	NS

Means followed by the same letter(s) within a year and treatment group are not significantly different at 5 percent level of probability according to DMRT.

NS = Not Significant ** = Significant at 1% level of Significance * = Significant at 5% level of Significance

TABLE 6: Interaction between nitrogen and sulfur fertilizer rates on grain yield (kg/ha) of QPM varieties in 2006 wet season

Treatment	Nitrogen Rates (kg/ha)			
Sulfur Rates (kg/ha)	0	60	120	180
0	1935.67 f	3848.30 cde	4744.37 ab	4226.81 a-d
5	1766.56 f	3267.70 e	4805.74 a	4149.52 a-d
10	1642.33 f	3624.96 de	4506.37 abc	4124.96 a-d
15	2245.19 f	4355.15 abc	3963.74 cd	4085.78 bcd
S.E. ±	212.440			

Means followed by the same letter(s) are not significantly different at 5 percent level of probability according to DMRT

Interaction between nitrogen and sulfur significantly influenced some growth, yield and yield components. This was probably because both nitrogen and sulfur are important nutrients for growth and development which led to higher photosynthetic activities that resulted in the production of enough assimilate for subsequent translocation for higher yield. Sulfur and nitrogen relationships were established in terms of dry matter and yield in several crops in many studies (Jamal *et al.*, 2010). The utilization of nitrogen depends in a high degree on the balancing of nitrogen dose with the dose of sulfur (Grzebisz and Gaj 2007). Similar finding was reported by Muhammad, *et. al*., (2004) that grain number per ear was significantly affected by the interaction between N and S.

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