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EFFECTS OF INTERACTION BETWEEN NITROGEN, SULFUR AND VARIETY ON MAIZE GRAIN NITROGEN AND SULFUR CONTENT AT SAMARU, ZARIA

[1]Jaliya, M.M., [1]Sani, B.M., [2]Babaji, B. A., [1]Sani, Y.A., [2]Sharifai, A.I. & [3]Zongoma, A.M.
[1]National Agricultural Extension and Research Liaison Services (NAERLS) A.B.U., Zaria
[2]Department of Agronomy A.B.U., Zaria
[3]Department of Biological Sciences A.B.U., Zaria
Corresponding Author's e-mail: jaliyamm64@gmail.com

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 varieties used showed similarities in most parameters except in their maize grain S content where EV-99 gave higher than Obatanpa variety. The study showed that interaction between nitrogen and sulfur significantly influenced maize grain N and S content. Similarly interaction between QPM variety and sulfur also significantly influenced maize grain S content. It can be concluded that application of nitrogen and sulfur showed better result than application of only one of the nutrient; hence farmers should try to apply the two nutrients in maize production.

KEY WORDS: Quality protein maize, Nitrogen, Sulfur, Interaction and Uptake.

INTRODUCTION
Maize or corn is a cereal crop that is grown widely throughout the world in a range of agroecological environments. More maize is produced annually than any other grain. Maize was introduced into Africa in the 1500s and has since become one of Africa's dominant food crops. Like many other regions, it is consumed as a vegetable although it is a grain crop. Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America. All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. Worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa. Africa imports 28% of the required maize from countries outside the continent. Most maize production in Africa is rain fed. Irregular rainfall can trigger famines during occasional droughts. Ninety percent of white maize consumption is in Africa and Central America. It fetches premium prices in Southern Africa where it represents the main staple food. Yellow maize is preferred in most parts of South America and the Caribbean. It is also the preferred animal feed in many regions as it gives a yellow color to poultry, egg yolks and animal fat. Various species of stem borers rank as the most devastating maize pests in SSA. They can cause 20-40% losses during cultivation and 30-90% losses postharvest and during storage. Maize does not tolerate drought well and the grain can rot during storage in tropical climates. A lack of sunshine and nitrogen can reduce the production potential of the crop. Plant growth and crop productivity is greatly influenced by the availability of plant nutrients in soil which can be regulated by both native and applied nutrients in calcareous sandy soils (Janzen and Bettany, 1987). Poor availability of nutrients is a challenging issue for plant growth in calcareous sandy soil. There are numerous factors controlling plant nutrient uptake availability. Among them, high pH, electrical conductivity and $CaCO_3$ levels, are predominantly responsible for poor uptake and availability of plant nutrients (Kaya *et al*., 2009). Elemental sulfur(S) can be used as a nutrient and an acidifier (Lindemann *et al*., 1991; Neilsen *et al*., 1993). The acidity produced during elemental S oxidation increases the availability of nutrients such as P, Mn, Ca and SO_4 in soils (Lindemann *et al*., 1991), which may enhance the chemical and physical characteristics of alkaline and sodic soils (Wainwright, 1984). Plant nutrients availability and uptake ability in calcareous soil can be enhanced by acidification which has large cumulative effects on the overall N balance and on the amount of soil nitrogen reserves (Cassman *et al*., 2002). Increased application of nitrogen fertilizer increases sulfur response but may adversely affect crop quality by increasing its N/S ratio, leading to reduction of protein-nitrogen and an increase in nitrate-nitrogen, and other non-protein nitrogen fractions. Nitrogen and sulfur are utilized mostly for protein synthesis in plants and it is necessary for the synthesis of amino acids, proteins and other cellular components which play an important role in the

protection of plants against stress and pests (Luit *et al*., 1999). Sulfur is a constituent of the amino acids cysteine and methionine and hence, part of proteins which play an important role in the synthesis of vitamins and chlorophyll in the cell (Marschner, 1995; Kacar and Katkat, 2007). Sulfur uptake efficiency increases, and the deficiency symptom disappears, upon application of N fertilizer in the form of urea in S deficient soil (Murphy, 1999). Sulfur is considered one of the major essential plant nutrients and an amendment used for reclaiming alkaline and calcareous soils (Marschner, 1995).Maize as an oilseed crop is highly responsive to S; making maize an ideal crop for sulfur application in the forms of elemental S and ammonium sulfate or urea, especially in alkaline and calcareous soils (Ghosh *et al*., 2000). Sulfur as an essential nutrient, comes in the sixth level of essentiality after N, P, K, Ca and Mg. 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. Quantitative increase in yield of maize could thus be achieved by N and S enrichment of the soils of the savanna. Quality enhancement of maize through soil N and S enrichment from inorganic fertilizers are also considered necessary for the production of QPM.

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, nutrient uptake and protein content of grains.

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. Rainfall normally establish as between mid-May to early June and peaks in July/August. Annual precipitation ranges between 800 – 1300 mm, with an average of 1100mm. The dry season starts about mid-October to late April. The hottest months are those preceding the rains (March/April) with temperatures of 27ºC and above. The coldest months are from November to January which period is characterized by the dry harmatan wind from the northeast when temperatures average 10–15ºC minimum and 21-36ºC maximum. 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, nutrient uptake and protein content of grains. The experiment was replicated three times. Borders between plots within a replication were separated by one metre spacing and between replications by spacing of 1.5 m. Gross plot size was 6 ridges *i.e.* 4.5 m by 2.5 m, giving an area of 11.25 m^2, while net plot size was 4 ridges *i.e.* 3.0 m by 1.5m with an area of 4.5 m^2.The two varieties used for the trials were open pollinated quality protein maize namely Obatanpa and EV-99; both were sourced from Institute for Agricultural Research Ahmadu Bello University Zaria. Obatanpa is a non tillering variety, erect, medium maturing with 106 to 110 days to physiological maturity. The plant height is 150–245 cm, while the plant colour is green. Potential grain yield of Obatanpa is 5.8 t/ha (Ado *et al*., 2009). The seed characteristics shows that the row arrangement is straight with 14 – 18 rows per cob, the kernel is white and kernel type is dent/flint. Obatanpa has high essential amino acids, lysine (3.9%) and tryptophan (1.1%) about 56% higher than normal maize with protein content of 10 – 12%. In addition to high yield, it is tolerant to striga infestation, stem borer and maize streak virus (MSV). EV – 99 is medium maturing at about 58 days to mid-silking with 170 cm in height, white seeded kernels. Adapted to lowland tropics with days to maturity of 90 – 95 days, high yield with potential yield of 5.5 t/ha. It is tolerant to *Striga hermonthica* and resistant to maize streak virus (Ado *et al*., 2009). Soils were randomly sampled from the experimental site before land preparation each year, at the depth of 0–30cm 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. Grain N and S content was also analyzed after harvest to observe effects of treatments on the uptake of N and S by grain. 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 on 11th and 9th July in 2006, 2007 respectively and 17th June in 2008 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. This gave plant population of 53,333 plants per hectare. 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}). Nitrogen for each rate was applied in two doses of 75% and 25%. First dose of N was applied at 3 weeks after sowing along with the whole of P, K and S, while the second dose was applied at 6 weeks after sowing at the time of remoulding. 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. Chemical weed control was not applied during this trial. Stem borer infestation was observed at 3 weeks after sowing, which was controlled by spraying with a combination of cypermethrin and dimethoate at the rate of 0.03 and 0.25 kg active ingredient per hectare respectively. No disease was observed throughout the period of the trial. Grains were randomly selected from each plot sun dried and ground into powder using electrical grinder. The powder was then sieved using 1mm-mesh sieve and one gram was used for laboratory analysis for N and S. One gram of the sieved sample was digested using sulfuric acid and perchloric acid with copper and sodium sulfate acting as catalysts. The digest was then used to determine N and S content of the grains. Part of the digest was distilled into boric acid and the distillate was then titrated against a standard hydrochloric acid (HCl) and the percent N and S contents were determined from the titre using Macro – Kjedhal (Bremner, 1965; IITA, 1975). Data collected were subjected to statistical analysis of variance and means of treatments were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955).

RESULTS

Maize grain analysis after harvest 2006 (N g/kg)

Maize grain N content was significantly influenced by interaction between nitrogen and sulfur fertilizers in 2006 (Table 1). When sulfur rates were observed by keeping nitrogen rates constant, at 0 kg N/ha similar but significantly higher maize grain N content were produced by 5 and 15 kg S/ha than 0 and 10 kg S/ha. At 60 and 180 kg N/ha, variation between sulfur rates did not affect maize grain N content. However, at 120 kg N/ha application of 5 kg S/ha produced significantly higher maize grain N content than the other S rates which were statistically similar. Keeping sulfur rates constant and varying nitrogen rates, interaction of 15 kg S/ha and all the N rates did not affect maize grain N content. At 0 and 10 kg S/ha, increase in nitrogen from 0 to 60 kg N/ha significantly increased maize grin N content but further increase up to 180 kg N/ha did not affect the parameter. At 5 kg S/ha, application of 120 kg N/ha produced significantly higher maize grain N content than the other N rates which were statistically similar.

Maize grain analysis after harvest 2007 (N g/kg)

Maize grain N content was significantly influenced by interaction between nitrogen and sulfur in 2007 (Table 1). Interaction between 0, 60 and 180 kg N/ha and all the sulfur rates showed no significant difference in maize grain N content. A significantly lower maize grain N content was observed from interaction between 120 kg N/ha and 15 kg S/ha compared to its interaction with other sulfur rates which were statistically similar. It was also observed that when 0 and 5 kg S/ha interacts with all the N rates, there was no significant change in maize grain N content. However, when interaction between 10 and 15 kg S/ha was observed a significantly higher maize grain N content was produced in their interaction with 120 kg N/ha compared to their interaction with other N rates which produced statistically similar values.

TABLE: 1 Effects of nitrogen and sulfur fertilizer interaction on maize grain N and S content.

Treatment	0kg S/ha	5kg S/ha	10kg S/ha	15kg S/ha
Maize Grain Analysis After Harvest 2006 (N g/kg)				
0 kg N/ha	11.325 cd	12.675 b	11.075 d	12.6 b
60 kg N/ha	12.55 b	12.05 bcd	12.625 b	11.725 bcd
120 kg N/ha	11.975 bcd	14.05 a	12.25 bcd	12.4 bc
180 kg N/ha	12.05 bcd	12.375 bc	12.35 bc	12.125 bcd
S.E. ±	0.35941			
Maize grain analysis after harvest 2007 (N g/kg)				
0 kg N/ha	13.345 abc	14.015 ab	12.7775 bc	13.865 ab
60 kg N/ha	13.1525 abc	13.0975 abc	12.075 c	13.1975 abc
120 kg N/ha	13.0175 abc	13.875 ab	14.445 a	11.995 c
180 kg N/ha	13.795 ab	12.8075 bc	12.84 bc	14.3825 ab
S.E. ±	0.4718			
Maize grain analysis after harvest (S mg/kg) 2006				
0 kg N/ha	925 b-e	975 bcd	1050 abc	950 bcd
60 kg N/ha	875 cde	975 bcd	950 bcd	1075 ab
120 kg N/ha	1075 ab	825 de	1175 a	900 b-e
180 kg N/ha	875 cde	850 de	650 f	750 e
S.E. ±	53.805			
Maize grain analysis after harvest 2007 (S g/kg)				
0 kg N/ha	1000.29 b-f	1000.29 b-f	1075.05 bcd	1075.05 bcd
60 kg N/ha	900.145 efg	1100.195 bc	1050.148 b-e	900.19 efg
120 kg N/ha	950.22 c-f	1150.405 ab	1250.273 a	800.3575 g
180 kg N/ha	925.1175 d-g	975.1525 c-f	875.2175 fg	975.255 c-f
S.E. ±	47.213			

Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significance using DMRT

Maize grain analysis after harvest (S mg/kg) 2006

Maize grain sulfur content as influenced by interaction between nitrogen and sulfur fertilizers in 2006 is given in Table 1. Varying levels of sulfur and keeping nitrogen rates constant, at 0 kg N/ha there was no significant change in maize grain S content between S rates applied. Lower maize grain S content was produced by 0 kg S/ha than other S rates though at par with 5 and 10 kg S/ha when 60 kg N/ha was observed. At 120 kg N/ha, application of 10 kg S/ha produced higher S content though at par with 0 kg S/ha. At 180 kg N/ha a significantly lower maize grain S content was produced when 10 kg S/ha was applied than other S rates which were statistically similar. Keeping sulfur rates constant, at

0 kg S/ha higher maize grain S content was produced by 120 kg N/ha. There was no significant difference between N rates when 5 kg S/ha was applied. At 10 kg S/ha, a significantly lower maize grain S content was produced when 180 kg N/ha was applied. However, at 15 kg S/ha, increase in N rate from 0 up to 120 kg N/ha did not affect maize grain S content, but further increase to 180 kg N/ha reduced maize grain S content though at par with 120 kg N/ha. Generally highest S content was produced by interaction between 10 kg S/ha and 120 kg N/ha while the lowest was produced by interaction between 10 kg S/ha and 180 kg N/ha.

Maize grain analysis after harvest 2007 (S g/kg)

Keeping nitrogen rates constant and varying the sulfur rates showed no significant effect by the interaction between nitrogen and sulfur at 0 and 180 kg N/ha (Table 1). Higher maize grain S content was given by 5 kg S/ha at 60 kg N/ha compared to the other S rates which were statistically similar. Increase in sulfur rate from 0 kg S/ha to 5 kg S/ha significantly increased maize grain S content, but further increase to 10 kg S/ha did not affect the parameter. However, increase to 15 kg S/ha significantly reduced the parameter. When nitrogen were varied with sulfur kept constant, there was no significant difference among the nitrogen rates at 0 kg S/ha. At 5 kg S/ha, increase in nitrogen from 0 kg N/ha up to 120 kg N/ha did not affect the parameter but further increase to 180 kg N/ha reduced the parameter but at par with 0 and 60 kg N/ha. At 10 kg S/ha, application of 120 kg N/ha significantly produced higher maize grain S content than the other N rates, while further increase to 180 kg N/ha significantly reduced the parameter. At 15 kg S/ha, plot with no nitrogen application produced higher maize grain S content though at par with 180 kg N/ha. Highest maize grain S content was produced by the interaction between 10 kg S/ha and 120 kg N/ha while the lowest vaue was produced by interaction between 15 kg S/ha and 120 kg N/ha.

Maize grain analysis after harvest (S mg/kg) 2006

Table 2 shows interaction between QPM variety and sulfur fertilizer, whereby in 2006 observation across sulfur rates indicates that increase in sulfur rate from 0 to 5 kg S/ha significantly increased maize grain S content in Obatanpa but further increase to 10 kg S/ha did not affect the parameter. However, increase to 15 kg S/ha significantly reduced the parameter. When EV-99 was observed, increase from 0 to 5 kg S/ha significantly reduced maize grain S content, but further increase to 10 kg S/ha did not affect the parameter. Increase to 15 kg S/ha significantly reduced the parameter. Observation across the varieties indicated that EV-99 variety produced significantly higher maize grain S content than Obatanpa variety but only when 0 and 15 kg S were applied.

Maize grain analysis after harvest 2007 (S mg/kg)

Keeping variety constant and varying sulfur rates, Obatanpa variety did not differ in its maize grain S content after harvest when sulfur rate increase from 0 up to 15 kg S/ha (Table 2). Taking EV-99 variety across the sulfur rates, 0 and 10 kg S/ha produced similar but significantly higher maize grain S content than the other rates which were statistically similar. Across the varieties keeping sulfur rates constant, EV-99 variety produced significantly higher maize grain S content than Obatanpa variety only when 0 kg S/ha was applied.

Maize grain analysis after harvest 2008 (S mg/kg)

Significant interaction between variety and sulfur in 2008 indicates that when varieties were kept constant and sulfur rates varied, Obatanpa variety did not differ in its maize grain S content by increasing sulfur rate from 0 to 10 kg S/ha. However, further increase to 15 kg S/ha significantly increased the parameter. When EV-99 variety was considered, 0 and 15 kg S/ha produced similar and significantly higher maize grain S content than the other S rates which were statistically similar. When sulfur rates were kept constant and varieties varied, at 0 and 15 kg S/ha EV-99 variety produced significantly higher maize grain S content than Obatanpa. At 5 and 10 kg S/ha the two varieties did not differ in their maize grain S content.

TABLE 2: Effects of variety and sulfur fertilizer interaction on maize grain N and S content

Treatment	0kg S/ha	5kg S/ha	10kg S/ha	15kg S/ha
	Maize grain analysis after harvest (S mg/kg) 2006			
Obatampa (V1)	862.5 c	962.5 b	1000 b	662.5 d
EV – 99 (V2)	1087.5 a	975 b	987.5 b	900 c
S.E.±	19.264			
	Maize grain analysis after harvest 2007 (S mg/kg)			
Obatampa (V1)	937.6713 c	1012.723 bc	1012.884 bc	925.1988 c
EV – 99 (V2)	1137.669 a	962.6163 c	1062.744 ab	950.1725 c
S.E.±	31.527			
	Maize grain analysis after harvest 2008 (S mg/kg)			
Obatampa (V1)	1212.5 cd	1275 bcd	1187.5 d	1337.5 b
EV – 99 (V2)	1487.5 a	1287.5 bc	1225 cd	1425 a
S.E.±	28.33			

Means followed by the same letter(s) within a treatment group are not significantly different at 5 percent level of significance using DMRT

DISCUSSION

Higher maize grain N and S content was observed from interaction between applied fertilizer than when only one of the fertilizer was applied. This is an indication that presence of one of the fertilizers enhances the uptake of

the other. Fazli *et al.* (2008) reported that lack of S limits the efficiency of added N. Therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizer. A number of studies indicated synergistic effect of combined application of S and N on the uptake of these nutrients by maize and rapeseed (Fazli *et al.,* 2008). Sulfur addition, however, significantly increased the percent N in grain. Sulfur is an important nutrient for plant growth and development. Sulfur interactions with nitrogen are directly related to the alteration of physiological and biochemical responses of crops, and thus required to be studied in depth. This would help to understand nutritional behavior of sulfur in relation to nitrogen nutrients and provide guidelines for inventing balanced fertilizer recommendations in order to optimize yield and quality of crops (Fazli *et al.,* 2008, Jamal, 2010). Regardless of the levels of elemental S, N fertilizer had positive influence on N uptake by maize. The results coincide with the findings of Chaubey *et al*. (1993) who observed that, the increased N contents of linseed grain and straw was obtained by the application of sulfur in sandy and loam soils.
Interaction between EV-99 variety and sulfur fertilizer gave higher maize S content than interaction between Obatanpa variety and sulfur fertilizer. This result corroborates with a report by (Hassen *et al*., 2006) that crop varieties differ in their nutrient uptake, when grains N content of the Melkassa I variety was found to be better than control at 64 kg N/ha.

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