# UPTAKE OF NITROGEN AND SULFUR AS INFLUENCED BY INTERACTION BETWEEN MAIZE VARIETY AND NITROGEN FERTILIZER AT SAMARU, ZARIA

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**ABSTRACT**
Experiments were conducted during the normal cultivation season of 2006, 2007 and 2008 at the Institute for Agricultural Research (IAR) farm, Samaru, in the northern Guinea Savanna of Nigeria to evaluate the responses of quality protein maize (QPM) varieties to applied nitrogen and sulfur fertilizers. The treatments consisted of two quality protein maize varieties (Obatanpa and EV-99), four rates of nitrogen (0, 60, 120 and 180 kg N/ha) and four rates of sulfur (0, 5, 10 and 15 kg S/ha) fertilizers. The experiment was laid out in a split plot design with variety and nitrogen in the main plot and sulfur in the sub-plot and replicated three times. The results indicate that uptake of N and S was significantly influenced by interaction between variety and nitrogen. Obatanpa variety was more responsive to the effect of interaction between variety and nitrogen than EV-99 variety. The interaction effect was independent of variety or nitrogen rate. It was concluded that QPM variety and nitrogen interaction significantly enhanced uptake of both nitrogen and sulfur nutrients.

**Key Words:** Quality protein maize, variety, nitrogen, sulfur and interaction.
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## INTRODUCTION

Maize or corn is a cereal crop that is grown widely throughout the world in a range of agroecological environments [1]. More maize is produced annually than any other grain. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red are the most common types. The white and yellow varieties are preferred by most people depending on the region. 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. Worldwide production of maize is 785 million tons, with the largest producer, the United States, produces 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 [1].

Most maize production in Africa is rain fed. Irregular rainfall can trigger famines during occasional droughts. According to 2007 FAO estimates, 158 million hectares of maize are harvested worldwide. Africa harvests 29 million hectares, with Nigeria, the largest producer in SSA, harvesting 3%, followed by Tanzania. 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. The quality protein maize (QPM), contains nearly twice as much usable protein as other maize (or corn) grown in the tropics and yields 10% more grain than traditional varieties of maize [1].

In Central and South America, Africa, and Asia, several hundred million people rely on maize as their principal daily food, for weaning babies, and for feeding livestock [2]. Unfortunately normal varieties of maize (corn) have two significant flaws. They lack the full range of amino acids, being deficient in lysine and tryptophan, needed to produce proteins, and has its niacin (vitamin $B_3$) bound in an indigestible complex QPM produces 70-100% more of lysine and tryptophan than the most modern varieties of tropical maize. These two amino acids allow the body to manufacture complete proteins, thereby eliminating wet-malnutrition. In addition, tryptophan can be converted in the body to Niacin, which theoretically reduces the incidence of Pellagra [2].

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 [3] This was evident from a trial by [4] where 422 children were fed with either QPM or normal maize in Ghana. The result indicated that children in the QPM group had significantly fewer sick days and less stunting, compared to children in the normal maize group.

Nitrogen is a major plant nutrient for growth and makes up 1 to 4% of dry matter of plants [5]. It is a component of protein and nucleic acids and when N is sub-optimal; growth is reduced [6]. Nitrogen is the most limiting nutrient in the Savanna soils where the soils are predominantly coarse textured and characteristically low in organic matter. 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 the 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 [7]. 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 ($SO_2$) [7].

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. This investigation was therefore, aimed at evaluating the effects of nitrogen and sulfur on quality protein maize (QPM) varieties with respect to nutrient uptake.

## MATERIALS AND 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 establishes between mid-May to early June and peaks in July/August. Annual precipitation ranges between 800-1300 mm, with an average of 1100 mm. The dry season starts about mid-October to late April. The hottest months are those preceding the rains (March/April) with temperatures of 27$^o$C and above. The coldest months are from November to January, which is characterized by the dry harmatan wind from the northeast when temperatures average 10-15$^o$C minimum and 21-36$^o$C maximum.

The experiment was laid out in split plot designed 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 1 m spacing and between replications by spacing of 1.5 m. Gross plot size was 4.5 m by 2.5 m, giving an area of 11.25 $m^2$, while net plot size was 3.0 m by 1.5 m 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 the 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 [8]. The seed characteristics show 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%) which is about 56% higher than that of normal maize. It also has a protein content of 10-12%. In addition to high yield, it is tolerant to *Striga* infestation, stem borer and maize streak virus (MSV). The EV-99 is medium variety maturing at about 58 days to mid-silking with 170 cm in height, white seeded kernels. It is adapted to lowland tropics with days to maturity of 90-95 days. It has a potential yield of 5.5 t/ha. It is tolerant to *Striga hermonthica* and resistant to maize streak virus [8].

Soils were randomly sampled from the experimental site before land preparation each year, at the depth of 0-30 cm. A composite sample was taken, dried, ground and sieved using 1 mm sieve. The composite sample in each year was taken to laboratory and analyzed for the determination of physical and chemical properties. Total nitrogen, was determined by macro-Kjeldahl extraction [9]. Available phosphorus was determined by Bray 1 method [10]. Exchangeable cations were determined from ammonium acetate leachate [11], using atomic absorption spectrophotometry for calcium (Ca) and magnesium (Mg), and flame photometry for sodium (Na) and potassium (K). Soils were also sampled from each plot after harvest and analyzed for N and S content using Kjeldahl and Turbidimetric Methods [12]. Plant tissue analysis was also carried out by cutting 5 ear and flag leaves from each plot (outside the net plot) at 50% tasselling to verify the uptake of N and S by the plant in each plot using Kjeldahl and Turbidimetric Methods [12].
The land was double harrowed and then ridged 75 cm apart. Plots were demarcated after ridging with well-formed borders between plots (1 m) and replications (1.5 m) to minimize nutrient seepage. Sowing was done by hand on 11$^{th}$ and 9$^{th}$ July in 2006, 2007 respectively and 17$^{th}$ June in 2008. Two seeds were planted per hole at the spacing of 25cm between stands. Seedlings were later thinned to one plant per stand at two weeks after sowing. This gave a plant population of 53,333 plants per hectare.

The nutrients applied were N, P, K and S. 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 a hoe 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. 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.

**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 |

Five plants were tagged in each plot for the measurement of growth parameters, while yield parameters were measured from the net plots. Data collected were subjected to analysis of variance and means of treatments were compared using Duncan Multiple Range Test (DMRT) [13].

## RESULTS

### Flag leaf N content (g/kg) as influenced by variety and nitrogen interaction in 2006

Flag leaf analysis in 2006 showed a significant effect of variety and nitrogen interaction on N uptake (Table 2). Interaction between Obatanpa variety and all the nitrogen rates did not affect N uptake. Higher N uptake was observed when EV-99 variety interacted with 180 kg N/ha, although this was statistically similar with the effect of 120 kg N/ha. When the interaction effect was observed across the varieties, the two varieties did not differ in their N uptake at each nitrogen rate. Interaction between EV-99 and 180 kg N/ha produced the best result in terms of N uptake by flag leaf in 2006.

### Ear leaf S content (mg/kg) as influenced by variety and nitrogen interaction in 2006

Interaction between maize variety and nitrogen significantly influenced sulfur uptake in 2006 (Table 2). Considering varieties across the nitrogen rates, S uptake by Obatanpa variety did not differ at all the nitrogen rates. However, when EV-99 was observed, increase in nitrogen from 0 up to 120 kg N/ha did not affect S uptake, but further increase to 180 kg N/ha increased N uptake though this was at par with 120 kg N/ha. Keeping nitrogen rates constant and varying varieties, the two varieties did not differ in their ear leaf S content at all the nitrogen rates.

### Flag leaf N content (g/kg) as influenced by variety and nitrogen interaction in 2007

Significant effect of interaction between variety and nitrogen rate on uptake of nitrogen by flag was observed in 2007 (Table 2). Keeping variety constant and varying nitrogen rates showed that interaction between both varieties and 60 kg N/ha significantly influenced N uptake by the flag leaf more than any other interaction in 2007. When each nitrogen rate was observed across the varieties, interaction of 60 and 120 kg N/ha and both varieties produced similar result in terms of N uptake. However, interaction between 0 kg N/ha and EV-99 variety resulted in higher N uptake than Obatanpa, whereas interaction between 180 kg N/ha and Obatanpa variety influenced higher N absorption than EV-99.

### Ear Leaf N content (g/kg) as influenced by variety and nitrogen interaction in 2007

Quality protein maize N uptake was significantly influenced by interaction between QPM variety and nitrogen rates in 2007 (Table 2). Interaction between Obatanpa variety and all the nitrogen rates did not significantly affect N uptake. However, when EV-99 interacted with 0 kg N/ha, higher N uptake was observed though this was at par with 120 kg N/ha. On the other hand when nitrogen rates were kept constant and maize varieties varied, significant difference was only observed when varieties interacted with 0 kg N/ha where EV-99 variety significantly showed higher N uptake than Obatanpa.

**Table 2:** Effect of interaction between maize variety and nitrogen on leaf nitrogen and sulfur content at 50% tasselling grown under rainfall condition at Samaru

| Treatment | 0 kg N/ha | 60 kg N/ha | 120 kg N/ha | 180 kg N/ha |
|---|---|---|---|---|
| | **Ear leaf N (g/kg) 2007** | | | |
| **Obatampa (V1)** | 21.71b | 22.73 ab | 19.69 b | 21.55 b |
| **EV – 99 (V2)** | 25.48 a | 20.58 b | 22.98 ab | 21.79 b |
| **S.E.±** | 1.038 | | | |
| | **Flag leaves N (g/kg) 2006** | | | |
| **Obatampa (V1)** | 19.31 abc | 17.98abc | 19.56ab | 18.10 abc |
| **EV – 99 (V2)** | 17.68 bc | 17.58 c | 17.97 abc | 20.29 a |
| **S.E.±** | 0.567 | | | |
| | **Flag leaf N (g/kg) 2007** | | | |
| **Obatampa (V1)** | 22.54 cd | 25.39 a | 23.64 bc | 23.84 b |
| **EV – 99 (V2)** | 23.85 b | 25.61a | 22.65 bcd | 21.58 d |
| **S.E.±** | 0.410 | | | |
| | **Flag leaf N (g/kg) 2008** | | | |
| **Obatampa (V1)** | 18.60 de | 23.95 a | 21.47625 bc | 21.53125 bc |
| **EV – 99 (V2)** | 18.83 de | 17.93e | 23.26ab | 20.27cd |
| **S.E.±** | 0.618 | | | |
| | **Ear leaves S (mg/kg) 2006** | | | |
| **Obatampa (V1)** | 507.50 abc | 382.50 abc | 551.25 ab | 501.25 abc |
| **EV – 99 (V2)** | 205.00 bc | 172.50 c | 315.00 abc | 606.25 a |
| **S.E.±** | 68.776 | | | |
| | **Ear leaf (S mg/kg) 2007** | | | |
| **Obatampa (V1)** | 260.37 bcd | 228.00 bcd | 286.79 bc | 109.44 e |
| **EV – 99 (V2)** | 456.63 a | 158.39 de | 190.63 cde | 324.54 b |
| **S.E.±** | 35.772 | | | |
| | **Ear leaf (S mg/kg) 2008** | | | |
| **Obatampa (V1)** | 12350 de | 15575 a | 13600 bc | 14687.5 ab |
| **EV – 99 (V2)** | 11712.5 e | 12975 cd | 14700 ab | 12837.5 cde |
| **S.E.±** | 375.45 | | | |
| | **Flag leaf (S mg/kg) 2008** | | | |
| **Obatampa (V1)** | 17175 e | 18012.5 cd | 18125 abc | 18362.5 ab |
| **EV – 99 (V2)** | 18237.5 abc | 18025 bcd | 18587.5 a | 17650 d |
| **S.E.±** | 160.53 | | | |

**Ear Leaf S content (mg/kg) as influenced by variety and nitrogen interaction in 2007**

Table 2 shows a significant interaction between variety and nitrogen on sulfur uptake by maize ear leaf in 2007. Increase in nitrogen from 0 up to 120 kg N/ha did not affect ear leaf S content as observed when Obatanpa ear leaf was analyzed. Further increase to 180 kg N/ha significantly increased S content of the ear leaf. The response of EV-99 variety indicated that when no nitrogen was applied, a significantly higher S uptake was observed compared to the other rates. Application of 60 and 120 kg N/ha produced similar but statistically lower S content in the ear leaf than the other rates. Comparing the varieties by keeping nitrogen rates constant, EV-99 variety was better than Obatanpa at 0 and 180 kg N/ha. However, uptake of S by the two varieties was statistically similar at 60 and 120 kg N/ha.

**Flag Leaf N content (g/kg) as influenced by variety and nitrogen interaction in 2008**

Variety and nitrogen interaction significantly influenced nitrogen uptake by the flag leaf in 2008. When varieties were observed across nitrogen rates, increase in nitrogen from 0 to 60 kg N/ha significantly increased uptake of nitrogen by Obatanpa variety. Further increase up to 180 kg N/ha significantly reduced N uptake. For EV-99 variety, application of 0 and 60 kg N/ha produced similar but lower N uptake. Increase in fertilizer from 60 to 120 kg N/ha significantly increased N uptake, but further increase to 180 kg N/ha significantly reduced N uptake. Observing the nitrogen rates across the varieties, the result indicated that the two varieties did not differ in their N uptake at 0, 120 and 180 kg N/ha. However, at 60 kg N/ha, interaction with Obatanpa variety significantly indicated higher N uptake than EV-99 variety.

**Flag and Ear Leaves S content (mg/kg) as influenced by variety and nitrogen interaction in 2008**

Laboratory analysis of flag leaf S content in 2008 revealed that uptake of S by maize varieties was significantly affected by interaction between variety and nitrogen. When nitrogen rates were compared across varieties, lower S was absorbed by Obatanpa variety at 0 kg N/ha than other nitrogen rates which were statistically similar. A significantly higher S content was observed when EV-99 variety was fertilized with 120 kg N/ha though at par with no nitrogen application. Comparison of the nitrogen rates across the varieties indicated that the two varieties were similar in terms of their S uptake when fertilized with 60 and 120 kg N/ha. However, EV-99 was better at 0 kg N/ha whereas Obatanpa was superior at 180 kg N/ha in terms of their S absorption.

Sulfur uptake by maize ear leaf was significantly affected by interaction between variety and nitrogen in 2008. When nitrogen rates were observed at constant variety, significantly lower sulfur was absorbed when no nitrogen was applied. This was followed by application of 120 kg N/ha, whereas application of 60 and 180 kg N/ha gave similar but statistically higher ear leaf S content. A significantly higher S was absorbed by EV-99 variety when 120 kg N/ha was applied compared to the other nitrogen rates which were statistically similar. When varieties were compared at constant nitrogen rate, there was no difference between varieties at 0 and 120 kg N/ha. However, at 60 and 180 kg N/ha Obatanpa gave significantly higher ear leaf S content than EV-99.

## DISCUSSION

Uptake of nitrogen and sulfur by quality protein maize (QPM) as influenced by interaction between QPM variety and nitrogen indicated that nitrogen interaction with EV-99 had better influence on N uptake than Obatanpa. This implies that varietal differences have significant influence on effect of interaction between variety and nitrogen on uptake of N and S by QPM. Similar observations were reported by [14] that the interaction between crop variety FH-810 and 300 kg N $ha^{-1}$ produced the highest number of grain rows/cob, cob diameter, number of grains/cob, 1000-grain weight, grain yield and seed protein contents.

Makhziah and Yonny [15] also reported results of an experiment which indicated that there was interaction between varieties and N rates on N uptake, nitrogen uptake efficiency and nitrogen utilization efficiency. The greater N uptake efficiency of Bisma and Pioneer-11 than Arjuna and local Madura. N utilization efficiency in different N rates was not different among varieties except Bisma that had the great N utilization efficiency in N 160 kg N/ha.

For nitrogen use efficiency (NUE), genetic variability and genotype x nitrogen fertilization level interactions reflecting differences in responsiveness have been observed in several studies on maize [16-22]. Roth *et al*. [23] reported that all nutrient uptake rates are dependent on the specific interactions of hybrids with their environment and management factors like plant density and soil nutrient availability.

## CONCLUSION

This research revealed that there was interaction between maize variety and nitrogen which influenced uptake of nitrogen and sulfur. It is therefore recommended that main effect of treatment factors should be backed up with their interaction effects so as to have complete observation.

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