Esxon Publishers

International Journal of Applied Research and Technology
ISSN 2277-0585

Publication details, including instructions for authors and subscription information:
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Available online: February 28, 2014

International Journal of Applied Research and Technology
Vol. 3, No. 2, February 2014. 113 – 119.

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(Received: 13 February 2014 / Accepted: 27 February 2014 / Published: 28 February 2014)

Abstract

These field trials were conducted in 2006, 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 quality protein maize (QPM) varieties. Treatments consisted of four (4) rates each of nitrogen (0, 60,120 and 180 kg N/ha) and sulfur fertilizer (0, 5, 10 and 15 kg S/ha) and two QPM varieties (Obatampa and EV – 99), laid out in a split plot design with variety and nitrogen in the main plots and sulfur in the sub plots and replicated three times. The results show that application of 120 kg N/ha produced significantly higher grain weight/plant grain weight/ha, number of grains/cob and 100-grain weight. Sulfur rates applied significantly influenced grain weight/plant grain weight/ha and number of grains/cob where the responses to S rates showed that the control produced lower values than the applied rates which were statistically similar. Obatampa variety was observed to produce higher number of grains/cob and 100-grain weight than EV – 99 variety. The study revealed that 120kg N/ha, 15 kg S/ha and Obatampa variety are the best combination for high yield in the northern Guinea savanna ecological zone of Nigeria.

Keywords: Quality Protein Maize, Nitrogen, Sulfur, Fertilizer, Grain and Cob.

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Subject: *0214-0223*

Introduction

Maize belongs to the family graminae, and probably originated from Mexico in Central America (Anon., 1994). The cultivation of maize spread from Mexico, northward to Canada and southward to Argentina (Anon., 1992). Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. The United States produces 40% of the world's harvest; other top producing countries include China, Brazil, Mexico, Indonesia, India, France and Argentina (FAO, 2009). Worldwide production was 817 million tonnes in 2009—more than rice (678 million tonnes) or wheat (682 million tonnes) (FAO, 2009). In 2009, over 159 million hectares of maize were planted worldwide, with a yield of over 5 tonnes/hectare. Production can be significantly higher in certain regions of the world. There is conflicting evidence to support a report by food and agriculture organization (FAO) that maize yield potential has increased over the past few decades (FAO, 2009). United States of America was the highest producer accounting for about half the world's total (43.1%) followed by Asia (32%), Latin America and Caribbean (16.3%). Africa produced 4.1% of the world's total with Nigeria producing 7.53 million tones or 1.1% of the world's figure (FAO, 2009). The world average yield was 4255kg per hectare. Average yield in USA was 8600 kg per hectare, while in Sub-Saharan Africa it was 1316 kg per hectare (Anon., 1992).

Effect of feeding 422 children, aged 4 and 9 months with either QPM or normal maize in Ghana indicated that children in the QPM group had significantly fewer sick days and less stunting, compared to children in the normal maize group (Akuamoa-Boateng, 2002). The protein quality of QPM cultivars was improved due to the presence of lysine and tryptophan in their endosperm, which are limited in common maize (Paiva, *et. al*., 1991). As a result of the improvement, the QPM's amino acid profile gives a good balance of total essential amino acids and has an amino acid score adjusted for digestibility of 67% compared to 28.5, 31.0, and 33.0% values found for pioneer, dent and flint maize, respectively. In common maize, the primary amino acid deficiencies include lysine, theonine and tryptophan (Zarkadas *et.al., 1995).* QPM may supply 70-73% of human protein requirement, compared to 46% for normal maize. The biological value of the protein (a value that measures how well the body can absorb protein) is 80% for QPM compared to 40 – 57% for normal maize and 86% for eggs (Bressani, 1992). The protein of QPM has 90% of the relative value (RV) of milk compared to 40% for normal maize (Badu-Apraku and Lum, 2010).

The International Maize and Wheat Improvement Center (CIMMYT), in collaboration with the International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Systems (NARS) in 17 countries of SSA, have developed a broad range of QPM cultivars responding to the needs of different countries and agro ecological zones. Commercial QPM seed is currently available in all collaborating countries and, based on average 2003-2005 seed production, approximately 200,000 hectares of land are being planted to QPM cultivars (Alan *et. al*., 2007). Among cereals, maize is an important food and feed crop which ranks first followed by wheat and rice in the world. Because of its expanded use in the agro-industries, it is recognized as a leading commercial crop of great agro-economic value (Muhammad *et. al*., 2004). The two varieties of QPM used for this study namely Obatampa and EV-99 were the most popular varieties in the study area, which have reached the hands of the farmers; hence their choice for the study.

Nitrogen is the motor of plant growth and makes up 1 to 4 percent of dry matter of the plants (Anon. 2000). Nitrogen 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. Likewise Sulfur is recognized as the fourth major nutrient after N, P and K. 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).

Materials and Methods

The experiment titled Effects of Nitrogen and Sulfur Fertilizers on Growth, Yield and Protein Content of Quality Protein Maize (Zea Mays L.) was conducted at the Institute for Agriculture Research (IAR) Farm, Samaru, Zaria (11° 11′ N; 07° 38′ E and 686 meters above sea level), located in the northern Guinea Savanna ecology. The experiment was carried out for three wet seasons, 2006, 2007 and 2008. The treatments consisted of two (2) open pollinated QPM varieties (Obatampa and EV – 99), four rates each of nitrogen (0, 60, 120 and 180kg N/ha) using urea and sulfur (0, 5, 10, and 15 kg S/ha) using potassium sulfate. The experiment was laid out in split plot design with nitrogen and variety in the main plot and sulfur in the subplot. The experiment was replicated three times, each replication comprised of thirty-two plots. Borders between plots within a replication were separated by one meter spacing and between replications by spacing of 1.5m. Gross plot size was 6 ridges i.e. 4.5m by 2.5m, giving an area of 11.25m^2, while net plot size was 4 ridges i.e. 3.0m by 1.5m with an area of 4.5m^2. Soils were randomly sampled from the experimental site before land preparation each year, at the depth of 0 – 30cm and analyzed for physical and chemical properties using Kjeldahl methods of laboratory analysis. Soils were also sampled from each plot after harvest and analyzed for N and S content. Plant tissue analysis was also carried out by cutting 5 ear and flag leaves from each plot (outside the net plot) to verify the uptake of N and S by the plant in each plot using Kjeldahl and Turbidimetric Methods Tabatabai M. A. (1974). Grain protein was also analyzed after harvesting to observe effects of the treatments on the grain protein content. S was determined by digestion using Nitric-Perchloric Acid digestion (Aluminum Block Method) and then the values were obtained by Turbidimetric Method for Sulfate S. While nitrogen was determined by Kjeldahl method.

The land was double harrowed and then ridged 75cm apart. Plots were demarcated after ridging with well-formed borders between plots and replications to minimize nutrient seepage. Sowing was done by hand in the month of June after rainfall to provide moisture for better germination. Two seeds were planted per hole at the spacing of 25cm between holes, and then 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. However, P and K were equally applied to all the plots while N and S were as treatment indicated (0, 60, 120 and 180 kg N ha^{-1} and 0, 5, 10 and 15 kg S ha^{-1}). N was applied in two equal doses, at 3 and 6 weeks after sowing when the whole of P, K, S and half of N were applied. Weeding was done by hoe to control weeds at 3 and 6 weeks after sowing. This was followed by remolding immediately after the second weeding and at the time of second dose of N fertilizer application. Stem borer infestation was observed, which was controlled by spraying with a broad spectrum insecticide called best Action at the rate of 1 litre per hectare. No disease was observed throughout the period of the trial.

Five plants were tagged in each plot for the measurement of growth parameters, while yield parameters were measured from the net plots. Growth parameters were assessed at 4, 8 and 12 weeks after sowing (WAS) while yield and yield components were measured after harvest among which the following were selected for the purpose of this paper. Number of grains per cob for five cobs in each plot was counted and later averages were worked out to give number of grains/cob. Cobs harvested from the five randomly selected plants used for measuring cob weight per plant were threshed and the grains weighed, the value of the grain weight was then divided by the number of plants (5) to give grain weight per plant.

Grain yield per hectare

Grain yield per plot was weighed and the value was extrapolated to per hectare basis. This was done using the following formula:

$$GH = \frac{GP\ x\ AH}{AP}$$

Where:

$$GH = \ Grain\ yield\ per\ hectare = \frac{0.371\ kg\ x\ 10000m^2}{4.5m^2}$$

GP = Grain weight per plot e.g. 0.371 kg
AH = Area of a hectare i.e. 10000m^2
AP = Area of Net plot i.e. 4.5m^2

100-grain weight

100 grains were randomly selected from the grains of each plot were weighed and recorded as per treatment.

Results and Discussion

Number of grains per cob of QPM varieties as influenced by Nitrogen and Sulfur fertilizers is presented in Table 1. Varieties differed significantly in their number of grains per cob in 2006, 2007 and averaged over years. Obatanpa produced significantly more grains per cob than EV-99 in both years and averaged over years. 100-Grain Weight as affected by N and S fertilizers is presented in Table 1. Varieties differed in 100-grain weight in 2006, 2008 and averaged over years with Obatanpa producing heavier grains than EV-99. Response to N was significant in 2006, 2007 and averaged over years. 100-grain weight increased as N was increased from 0 up to 120 kg N/ha. However, when N was increased to 180 kg N/ha the difference was not significant. The influence of sulfur and interactions between the treatment factors were not significant. Table 2 shows effects of N and S, on grain weight per plant, which did not differ between the two varieties. Significant increase was observed by the application of nitrogen from 0 up to 120 kg/ha, above which the increase was not significant. Sulfur had significant influence only in 2008 with 10 and 15 kg S/ha producing similar but heavier grains per plant compared to other sulfur rates which were statistically similar. No significant interaction was observed between the treatment factors.

Grain yield response to N and S is presented in Table 2. 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 3). 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. The combination of 0, 5, 10 kg S/ha and 120, 180 kg N/ha produced similar and significantly higher grain yield. Similar grain yield was also produced when 15 kg S/ha combined with 60 kg N/ha.

QPM varieties tested did not show significant variation for grain yield, {Sallah *et al*., (2003)}. Mani (2009) also reported that five QPM varieties Obatanpa, Mamaba, Susuma, Ev. 99 QPM and DMR-ESR QPM when evaluated the result showed that DMR ESR. QPM and Ev.99 QPM gave significantly higher yields and net return than the other three; this showed a similarity in some QPM varieties. Application of nitrogen significantly enhanced yield and yield components measured. 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). Application of sulfur did not significantly influence some of the parameters in all the three years of the trial. 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. Brady (1984) reported that cereal grains generally have low S requirements.

Conclusion and Recommendations

Field trials were conducted during 2006, 2007 and 2008 wet season to assess the effect of Nitrogen and Sulfur fertilizer rates on quality protein maize (QPM) varieties. Treatments consisted of four (4) Nitrogen rates (0, 60, 120 and 180 kg N/ha) and four (4) Sulfur fertilizer levels (0, 5, 10 and 15 kg S/ha), laid out in a split plot design and replicated three times. The results show that, Nitrogen rate of 120 kg N/ha produced significantly higher number of grains/cob, 100-grain weight, grain weight/plant and grain yield/ha in all the three years than the other lower N rates, which were statistically similar, but further increase to 180 kg N/ha did not affect the parameters. There was no significant effect of sulfur on both number of grains/cob, 100-grain weight, Grain weight/plant and Grain yield/Ha in all the years and their mean except on number of grains/cob in 2007, Grain weight/plant and Grain yield/Ha in 2008. A significantly higher number of grains per cob was recorded when 5 kg S/ha was applied compared to other rates. Interaction was not significant on both parameters, whereas Sulfur rate of 15kg S/ha produced heavier grains but only significantly different with grains produced by Sulfur rate of 0 and 5kg S/ha. Interaction between nitrogen and sulfur was significant only on grain yield/ha in 2006. Higher grain yield/ha was produced by the interaction of 60 kg N/ha and 10 kg S/ha while the interaction of 0 kg S/ha with all the nitrogen rates produced similar but significantly lower grain yield/ha than the other interactions. Obatampa variety was observed to produce higher values of the parameters than EV – 99 variety. The study revealed that 120 kg N/ha, 15 kg S/ha and Obatampa variety are the best combination for better yield and yield components in the Northern Guinea Savanna ecological zone of Nigeria.

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Tables

Table 1: Effects of Nitrogen and Sulfur Fertilizers on Number of Grains/cob and 100-Grain Weight of two Quality Protein Maize varieties in three years and the mean.

	Number of Grains/Cob				100-Grain Weight			
Treatment	2006	2007	2008	Mean	2006	2007	2008	Mean
QPM Variety								
Obatampa	415.1a	366.3a	403.9	411.4a	22.77 a	17.97	26.52 a	24.02 a
EV-99	398.0b	342.6b	391.9	396.0b	21.78 b	18.08	25.37 b	22.98 b
S.E. ±	5.56	3.40	7.63	3.65	0.287	0.319	0.321	0.172
Significance	*	*	NS	**	*	NS	*	**
Nitrogen Fertilizer (kg N/ha)								
0	338.6c	278.4c	375.6	350.9c	19.47 c	17.41	23.82 c	20.92 c
60	416.1b	347.8b	396.0	416.4b	22.18 b	17.98	25.72 b	23.36 b
120	455.6a	389.1a	417.2	435.7a	24.00 a	18.06	27.05 a	25.02 a
180	416.1b	402.7a	402.9	411.7a	23.45 a	18.64	27.20 a	24.70 a
S.E. ±	7.86	4.81	10.80	5.17	0.405	0.452	0.454	0.244
Significance	**	**	NS	**	**	NS	**	**
Sulfur Fertilizer (kg S/ha)								
0	409.9	322.6c	396.8	405.6	22.17	18.28	25.83	23.39
5	408.6	394.7a	406.7	407.9	22.08	18.10	26.39	23.51
10	394.9	350.4b	401.8	397.2	22.32	17.50	26.21	23.62
15	412.9	350.2b	386.4	404.1	22.54	18.22	25.36	23.48
S.E. ±	8.99	4.52	10.09	6.13	0.351	0.360	0.409	0.214
Significance	NS	**	NS	NS	NS	NS	NS	NS
Interaction								
VxN	NS	NS	NS	NS	NS	NS	NS	NS
VxS	NS	NS	NS	NS	NS	NS	NS	NS
NxS	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 2: Effects of nitrogen and sulfur fertilizers on grain weight per plant (g) and Grain Yield (kg/ha) of two quality protein maize varieties in three years and the mean.

	Grain Weight per Plant (g)				**Grain Yield (kg/ha)**			
Treatment	2006	2007	2008	Mean	2006	2007	2008	Mean
QPM Variety								
Obatanpa	67.6	67.6	95.4	76.8	3602.4	1980.0	5087.7	3556.7
EV-99	66.7	66.7	92.5	75.3	3559.2	2040.7	4934.7	3511.5
S.E. ±	2.21	2.21	2.00	1.24	118.10	76.10	106.75	58.82
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen Fertilizer (kg N/ha)								
0	35.6c	35.6c	60.3c	43.8c	1897.4 c	830.85 c	3217.0 c	1981.8 c
60	70.8b	70.8b	95.7b	79.1b	3774.0 b	2160.9 b	5101.3 b	3678.7 b
120	84.5a	84.5a	107.1a	92.0a	4505.1 a	2609.3 a	5711.9 a	4275.4 a
180	77.8a b	77.8ab	112.8a	89.4a	4146.8 ab	2440.3 ab	6014.6 a	4200.5 a
S.E. ±	3.13	3.13	2.83	1.75	167.02	107.61	150.97	83.18
Significance	**	**	**	**	* *	**	**	**
Sulfur Fertilizer (kg S/ha)								
0	69.2	69.2	91.3 b	76.5	3688.8	2120.3	4867.8 b	3559.0
5	65.6	65.6	93.4b	74.9	3497.4	2209.0	4983.2 ab	3563.2
10	65.2	65.2	101.3ab	77.2	3474.7	1776.0	5399.9 a	3550.2
15	68.7	68.7	89.9a	75.7	3662.5	1936.0	4793.8 b	3464.1
S.E. ±	1.99	2.46	2.96	1.52	106.22	121.54	157.97	79.49
Significance	NS	NS	*	NS	NS	NS	*	NS
Interaction								
VxN	NS	NS	NS	NS	NS	NS	NS	NS
VxS	NS	NS	NS	NS	NS	NS	NS	NS
NxS	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 3: Interaction between Nitrogen and Sulfur fertilizer rates on Grain Yield/ha of QPM varieties.

		Grain Yield/ha 2006		
Treatment	**0kg S/ha**	**5kg S/ha**	**10kg S/ha**	**15kg S/ha**
0 kg N/ha	1935.67 f	3848.30 cde	4744.37 ab	4226.81 a-d
60 kg N/ha	1766.56 f	3267.70 e	4805.74 a	4149.52 a-d
120 kg N/ha	1642.33 f	3624.96 de	4506.37 abc	4124.96 a-d
180 kg N/ha	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