ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

IMPROVED QUALITY PROTEIN MAIZE RESPONSE TO NPK FERTILIZER IN SUDAN SAVANNA AGRO-ECOLOGICAL ZONE OF GHANA

N. Abdul Rahman[1] and F. M. Tetteh[2]
[1]College of Tropical Agriculture, UST Kumasi, Ghana
[2]Soil Research Institute, P. M. B. Kwadaso-Kumasi, Ghana
E-Mail: abdulrahmannurudeen@yahoo.com

ABSTRACT

The experiment was conducted to determine improved quality protein and open pollinated maize (*obatanpa*) response to different rates of NPK fertilizer. Experiment was laid in RCBD with four replications. Treatment evaluated were 0-0-0-0, 0-90-90, 40-90-90, 80-90-90, 120-90-90, 160-90-90, 120-0-90, 120-45-90, 120-90-0 and 120-90-45 NPK kg/ha. The soil at site was *Tanchera* series (Ferric Lixisol, FAO, 2006). Results indicated that, number of cobs, cob weight, grain yield, stover weight, biological yield and harvest index responded significantly with increasing rates of N fertilizer in both seasons. In 2010, 160-90-90 obtained the highest yield and yield components and 120-90-90 recorded the highest yield and yield components in 2011 season. The least yield and yield components were obtained by treatment 0-0-0 and 0-90-90 plots. Application of different rates of P and K fertilizers at different rates did not significantly influence yield and yield components in both seasons. Correlation analysis showed a significant co-efficient (r) among NPK fertilizer, yield and yield component during 2010 and 2011 seasons. NPK fertilizer application on the average increased grain and biological yield by 768.7%, 96% in 2010 and 357.2%, 150.6% in 2011 over control plots. Application of N fertilizer may be used to increase yield and yield components of maize but application beyond 120 N kg/ha may not produce significant result in this agro-ecological zone of Ghana. However, due to poor nature of soils in the agro-ecological zone application of P and K fertilizer up to 45 kg/ha may be used to increase yield and yield components of maize.

Keywords: NPK fertilizer, quality protein maize, yield, savanna.

INTRODUCTION

Maize is an important crop in West Africa and a major staple in Ghana especially in the Northern part (Fosu *et al*., 2004). It is predominantly produced by smallholder resource poor farmers in Ghana. Average yield of maize is about 1.7 t/ha in Ghana (MoFA, 2011) compared to world average of 4.9 t/ha (Edgerton, 2009). The main constraints associated with low yields of maize are low soil fertility and low and blanket application of fertilizer to improved maize varieties.

Major maize producing areas in Ghana are forest, savanna and transitional agro-ecological zones. Soils in maize producing areas especially Northern savanna agro-ecological zones are low in OC (< 2%), total N (< 0.02%), available P (< 10 mg/kg) and exchangeable K (< 100 mg/kg) (Adu, 1969, 1995b; and Adu and Asiamah, 2003).

Fertilizer use is the core strategy to overcome low soil fertility depletion through nutrient mining and declined crop productivity. Boul and Stokes (1997) reported that fertilizer is responsible for large part of sustained increase in per-capital food production in the world. Maize is heavy feeder on nutrient. The major nutrients required for maize production are N, P, and K. Sipaseuth *et al*., (2007) reported that, N nutrient is the most limiting nutrient for maize production especially in humid and sub-humid tropics.

The use of old or blanket fertilizer recommendation together with improved varieties of maize has not given maximum yield. Therefore the need to up-date the fertilizer recommendation for improved maize variety using field trials. The objective of the study was to refine profitable NPK fertilizer recommendation for improved maize variety. And determine the most limiting nutrient for maize production in the Sudan savanna agro-ecological zone.

MATERIALS AND METHODS

Study area

The experiment was conducted in 2010 and 2011 growing season in the Sudan savanna agro-ecological zone of Ghana. The area lies roughly between 10^o 30’ and 11’’ North latitude of the equator and 0^o and 1’ 30’’ West longitude of the zero meridian and covers an area of 1765 km^2 along Ghana-Burkina Faso border. It measures roughly 50 km long and 55 km wide and has an altitude of 200 - 400 m above sea level (Adu, 1969; Nyarko *et al*., 1999). It has a mono-modal rainfall season which extends from April to October, with the heaviest rainfall mainly occurring between June and October. The mean annual rainfall is 1365 mm but the highest level is recorded in August (Nyarko *et al*., 1999). The mean monthly minimum temperature ranges from 18.9-25.7^{o}C and the mean monthly maximum temperature also ranges from 32.4-38.6^{O}C. The mean annual minimum and maximum temperatures are 22.3 and 34.3^{o}C, respectively (Adu, 1969). The mean annual relative humidity for a day is about 40 - 50% (Adu, 1969).

Experimental design

Randomized complete block design with 4 replications was used to set up experiment. Plot size was

4.8 m x 6 m. Treatments evaluated were 0-0-0, 0-90-90, 40-90-90, 80-90-90, 120-0-90, 120-45-90, 120-90-90, 120-90-0, 120-90-45, 160-90-90 NPK kg/ha respectively. The source of N nutrient was urea, P was triple super phosphate and K was muriate of potash. Obatanpa maize variety was planted at a spacing of 80 cm x 40 cm for the two seasons. Obatanpa variety was selected because it is widely accepted by farmers and consumers in Ghana. Badu-Apraku *et al*. (2004) reported that, it has also been formally released in other African countries such as Benin ((as Faaba), Togo, Mali (as Debunyuman), Guinea, Burkina Faso, Côte d'Ivoire, Senegal, Cameroon, Nigeria (as SAMMAZ 14), Mozambique (Susuma), Uganda, Ethiopia, Zimbabwe, Swaziland, Malawi, and South Africa.

Chemical analysis

Composite soil samples were taken at a depth of 0-20 and 20-40 cm and analyzed for pH (1:2.5 w/v 0.01 *M* $CaCl_2$), total N by Kjeldahl distillation and titration method (Bremner and Mulvaney, 1982), available P by Bray 1 extraction solution procedure (Bray and Kurtz, 1945), Exchangeable bases (Ca, Mg, K, and Na) content in the soil were determined in 1.0 *M* ammonium acetate extract (Thomas, 1982) and organic carbon by modified Walkley and Black procedure as described by Nelson and Sommers (1982).

Data collection

A known area of 9 m^2 was marked in middle of each plot for data collection on number of cobs at harvest, cob weight, and grain yield. Stover weight was measured as the weight of the number of above ground plants within the harvest area, total biomass as the sum of weights of stover, cob and husk and harvest index as ratio of grain yield and total biomass (biological yield).

Statistical analysis

General linear model of Statistics was used to analyze the above field data. Least significant difference test at 5% was used to separate treatment means which were significantly different. Pearson co-efficient of correlation at 5% were determined among treatments, yield and yield components.

RESULTS

Soil properties

The soil at the experimental site was *Tanchera* series (Ferric Lixisol FAO, 2006). The pH of the soil was acidic with an average value of 5.23 and 5.49 under 2010 and 2011 season, respectively (Table). The organic carbon and organic matter were generally very low with same averages of 0.22 %, 0.37 %, respectively under both 2010 and 2011 season. Average total nitrogen and available P were also low with similar averages for both seasons (Table-1). The results of the chemical analysis was in agreement with the findings of Adu (1969, 1995b); Adu and Asiamah (2003) that, the total N, available P and organic matter levels in soils of Sudan savanna agro-ecological zone of Ghana ranges from 0.02 % to 0.09%, trace and 8 mg/kg and less than 2 %, respectively.

Table-1. Chemical properties of Tanchera series (Ferric lixisol, FAO, 2006) at Navrongo.

Layer (cm)	**pH 1:1 H_2O**	**Org. C** (%)	**Org. M** (%)	**Total N** (%)	**Av. P** (mg/kg)	**Exch. K** (mg/kg)	**Ca** (mg/kg)	**Mg** (mg/kg)
2010 growing season								
0-20	5.15	0.28	0.48	0.04	7.46	54.56	0.47	0.34
20-40	5.30	0.15	0.26	0.03	3.19	58.59	1.60	0.94
2011 growing season								
0-20	5.64	0.26	0.45	0.05	7.95	41.70	2.10	0.30
20-40	5.33	0.17	0.29	0.01	3.17	59.61	1.45	0.50

Org. C = Organic Carbon, Org. M = Organic Matter, Total N = Total Nitrogen, Av. P = Available Phousphorus, Exch. K = Exchangeable Potassium, Ca = Calcium and Mg = Magnessium

Number of cobs at harvest

NPK fertilizer application showed a significant difference under number of cobs at a probability level of 0.01 during both 2010 and 2011 season (Table-2). Number of cobs responded significantly among N fertilizer rates in both 2010 and 2011 seasons. In 2010 season, 160-90-90 recorded the highest number of cobs but was not statistically different from number of cobs obtained under 120-90-90 (Table-3). P and K fertilizer rates did show any significant difference on number of cobs. In 2011, 120-90-90 obtained the highest number of cobs. P and K fertilizer rates did not significantly influence number of cobs (Table-3).

Treatment 0-90-90 recorded the least number of cobs among plots fertilized with NPK at different rates during both seasons. This confirms that N is the most limiting nutrient for maize production (Sipaseuth *et al*., 2007).

VOL. 9, NO. 5, MAY 2014 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

Table-2. NPK effect on no. of cobs, cob weight, grain yield, stover weight, biological yield and harvest index of maize.

Effect	No. of Cobs		Cob weight		Grain yield		Stover weight		Biological yield		Harvest index	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
	P Value											
NPK	0.002**	0.001**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.008**

** = significant at 0.01

Cob weight

There was significant difference among treatment under cob weight at probability 0.01 for both seasons (Table-2). In 2010 season, 160-90-90 had the highest cob weight but was not significantly different from cob weight obtained under 120-90-90 rate of N fertilizer (Table-3). Different rates of P and K fertilizer did not significantly affected cob weight (Table-3). In 2011, the highest cob weight was recorded by treatment 120-90-90 but was not significant different from cob weight obtained under 80-90-90, 1600-90-90 rates of N fertilizer. Cob weight was not significantly different under P and K rates (Table-3). The least cob weight was recorded under 0-90-90 plot among plots treated with different rates NPK during both seasons. Sipaseuth *et al*., 2007 reported that, N nutrient is the most limiting nutrient for maize production especially in humid and sub-humid tropics.

Table-3. Effect of NPK fertilizer on No. of cobs, cob, Stover weight, biological yield and harvest index of maize in Sudan savanna agro-ecological zone of Ghana during 2010 and 2011 growing seasons.

Treatment (NPK kg/ha)	**No. of cobs**		**Cob weight** (kg/ha)		**Stover weight** (kg/ha)		**Biological yield** (kg/ha)		**Harvest index** (%)	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
0-0-0	20625	11358	306.3	944.5	5231.3	1635.7	5625.0	4315.0	4.3	13.8
0-90-90	16875	15309	287.5	1620.4	5135.0	2178.3	5523.0	6197.0	4.2	15.8
40-90-90	29375	28642	1631.3	2749.8	5594.0	4432.2	8278.0	8583.0	18.2	25.7
80-90-90	40625	32593	2525	3388.7	7500.0	5418.6	10138.0	10408.0	16.9	25.9
120-90-90	36875	51728	3237.5	4212.9	8512.5	6758.2	12031.0	12910.0	21.5	26.1
160-90-90	48750	28642	4406.3	3207.0	9281.3	7612.7	14488.0	12902.0	24.3	20.2
120-0-90	38750	37531	3475.0	3868.8	8918.8	5541.8	12725.0	11184.0	21.4	29.0
120-45-90	37500	32099	2313.0	3379.2	8896.8	5719.6	12047.0	10704.0	18.5	25.1
120-90-0	34375	39012	2162.0	3664.2	9025.0	6565.7	11738.0	12106.0	17.2	24.4
120-90-45	37500	32099	243.8.0	3465.4	8387.3	6645.3	12281.0	12338.0	21.2	22.4
Lsd $_{(0.05)}$	13500	15242	1210.7	1087.7	1139.8	2139.0	286.6	2809.6	8.3	7.8

Lsd = least significant difference, No. = number

Stover weight

NPK fertilizer application showed a significant difference under Stover weight at a probability level of 0.01 during both 2010 and 2011 season (Table-2). Stover weight responded significantly among N fertilizer rates in both 2010 and 2011 seasons. In 2010 season, 160-90-90 had the highest sotver weight but was not statistically different from stover weight recorded under 120-90-90. P fertilizer rates did show any significant difference on Stover weight. K fertilizer rates significantly influence stover weight with 120-90-0 recording the highest Stover weight but was not significantly different from stover weight obtained under 120-90-90 (Table-3). In 2011, 160-90-90 obtained the highest Stover weight but was significantly different from stover weight recorded under 120-90-90. P and K fertilizer rates did not significantly influence stover weight (Table-3).

Grain yield

Grain yield was significantly affected by NPK fertilizer treatments at a probability level of 0.01 under both 2010 and 2012 seasons (Table-2). In both seasons grain yield responded significantly among N fertilizer rates but did not show significant respond among P rates. In 2010, 160-90-90 had the highest grain yield but was not significantly different from grain yield recorded under 120-90-90 (Figure-1a). There was significant difference among grain yield obtained under different K rates with 120-90-45 recording the highest grain yield but was not significantly different from grain yield under 120-90-90. In 2011, the highest grain yield was recorded under 120-

ARPN Journal of Agricultural and Biological Science

90-90 but was not significant different from 80-90-90 and 160-90-90 (Figure-1a). P and K rates did not show significant difference on grain yield during this season (Figures 1b and 1c). In both seasons, 0-90-90 obtained the least grain yield among plots treated with NPK at different rates, which is in agreement with findings of Sipaseuth *et al*. (2007).

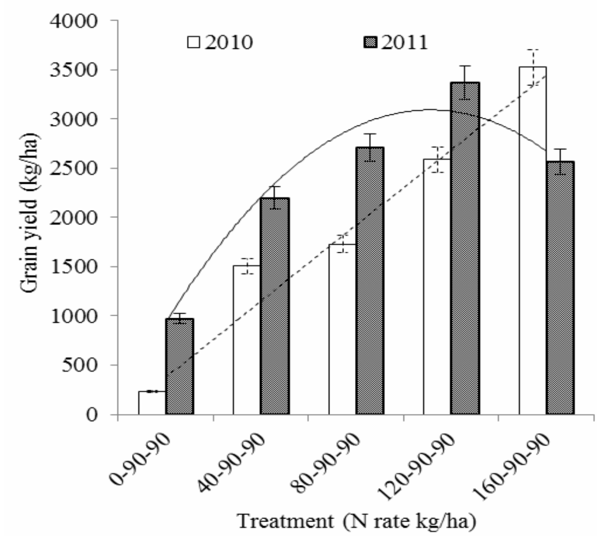

Figure-1(a). Maize grain yield as affected by different rate of N fertilizer during 2010 and 2011 seasons. Bars = Standard errors.

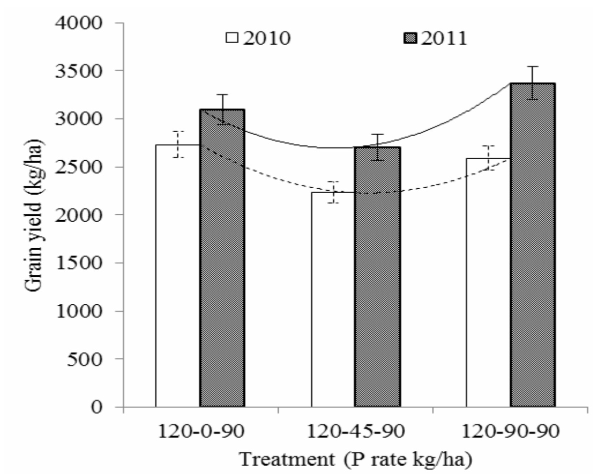

Figure-1(b). Maize grain yield as affected by different rate of P fertilizer during 2010 and 2011 seasons.

Figure-1. Maize grain yield as affected by different rate of NPK fertilizer during 2010 and 2011 growing seasons.

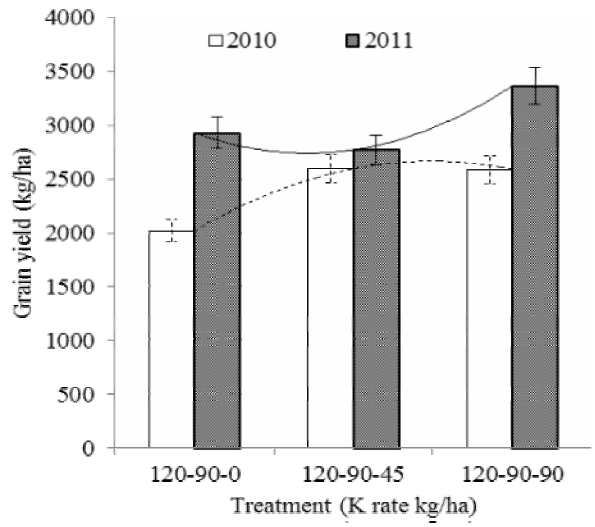

Figure-1(c). Maize grain yield as affected by different rate of K fertilizer during 2010 and 2011 seasons. Bars = Standard errors.

Biological yield was significantly influenced by NPK fertilizer application at a probability level of 0.01 (Table-2). There was significant response of N fertilizer rates on biological yield during the 2010 and 2011 seasons (Table-3). P and K fertilizer rates did not show significant response on biological yield during both 2010 and 2011 seasons (Table-3). In 20110, 160-90-90 obtained the highest biological yield while 120-90-90 recorded the highest biological yield under 2011 season but was not statistically different from biological yield obtained under 160-90-90 and 80-90-90 (Table-3).

Harvest index

NPK fertilizer significantly influence harvest index at a probability level of 0.01 (Table-2). Harvest index was significantly influenced by N rates of fertilizer during both 2010 and 2011 seasons. Treatment 160-90-90 recorded the highest harvest index during the 2010 season but was statistically different harvest index obtained under 120-90-90 and 80-90-90 (Table-3). However, P and K fertilizer rates did not significantly increased harvest index under both 2010 and 2011 season. In 2011, 120-90-90 obtained the highest harvest index but was not significantly different from harvest index recorded by 80-90-90 and 40-90-90. P and K fertilizer rates did not significantly influence harvest index (Table-3).

Correlation among NPK fertilizer, yield and yield component

NPK fertilizer application showed a significant correlation co-efficient (r) values at probability level of 0.01 among yield and yield components in both 2010 and 2011 growing seasons (Table-4). However, the correlation co-efficient between NPK fertilizer and harvest index was not significant in the 2011 season (Table-4).

Correlation co-efficient (r) values among number of cobs, cob weight, biological yield and harvest index were observed to be significant at probability level of 0.01 under grain yield during both 2010 and 2011 seasons (Table-4). This was in agreement with findings of Rafique *et al*. (2004) that, grain yield showed a highly significant correlation among grain yield, biological yield and harvest index.

Table-4. Co-efficient of correlation (r) among NPK fertilizer, yield and yield component of maize.

Variables	Treatment		Cob weight		Grain yield		Biological yield	
	2010	2011	2010	2011	2010	2011	2010	2011
Cob weight	0.707**	0.586**	-	-	-	-	-	-
Grain yield	0.742**	0.613**	0.858**	0.996**	-	-	-	-
Biological yield	0.896**	0.782**	0.816**	0.810**	0.840**	0.822**	-	-
Harvest index	0.616**	0.250ns	0.776**	0.781**	0.962**	0.780**	0.728**	0.329*

Ns = not significant, * = significant at 0.05 and ** = significant at 0.01

CONCLUSIONS

There was significant response of N fertilizer application on the yield and yield component of maize in both 2010 and 2011 season. N nutrient was the most limiting nutrient for maize production in the Sudan savanna agro-ecological zone of Ghana. Application of N fertilizer may be used to increase maize yield. However, application of N fertilizer beyond 120 kg/ha may not show significant response in yield on *Tanchera* series.

P and K fertilizer application did not show significant yield response of maize in both seasons in the Sudan savanna agro-ecological zone of Ghana. However, due to the poor nature of soils in the agro-ecological zone application of P and K fertilizer up to 45 may be recommended.

Based upon the significance of correlation co-efficient (r) among yield and yield component under NPK fertilizer, application of N fertilizer up to 120 kg/ha and P and K fertilizer up to 45 kg/ha may be used to increase yield of maize in the Sudan savanna agro-ecological zone of Ghana.

REFERENCES

Adu S. V. 1969. Soils of the Navrongo-Bawku area, Upper region, Ghana. Memoir Number 5. Soil Research Institute, Kumasi, Ghana.

Adu S. V. 1995b. Soils of the Nasia Basin, northern region, Ghana. Memoir Number 11. Soil Research Institute, Kumasi, Ghana.

Adu S. V. and Asiamah R. D. 2003. Soils of the Lawra-Wa area, Upper West region, Ghana. Memoir Number 18. Soil Research Institute, Kumasi, Ghana.

Badu-Apraku B., Fakorede M. A. B., Ajala S.O. and Fontem L. 2004. Strategies of WECAMAN to promote the adoption of sustainable maize production technologies in West and Central Africa. J. Food. Agric. Environ. 2(3 and 4): 106-113.

Bray I. L. and Kurtz L. T. 1945. Determination of Total organic and available form of phosphorus in soils. Soil Science 59: 39-45.

Bremner J. M. and Mulvaney V. A. 1982. Steam distillation methods for ammonium nitrate and nitrite. Anal. Chim. Acta. 32: 485-495.

Buol S. W. and Stokes M. L. 1997. Soil profile alteration under long-term high input agriculture. pp. 97-109. In: R.J. Buresh *et al*. (Eds.) Replenishing soil fertility in Africa. SSSA Spec. Publ. 51. SSSA, Madison, WI.

Edgerton M.D. 2009. Increasing food productivity to meet global needs for food, feed and fuel. Plant Physiology. 149: 7-13.

FAO. 2006. World Reference Base for Soil Resources, by IUSS-FAO. World Soil Resource Report No. 103. Rome, Italy.

Fosu M., Ronald F. and Vlek P. L. G. 2004. Improving maize yield in the Guinea Savannah zone of Ghana with leguminous cover crops and P K fertilization. Journal of Agronomy 3 (2): 115-121.

MoFA. 2011. Ministry Of Food and Agriculture. Agriculture in Ghana; facts and figures. Statistics, Research and Information Directorate (SRID).

Nelson D. W. and Sommers L. W. 1982. Total carbon, organic carbon and organic matter. In: Page AL, Miller RH and Keeney DR (Eds.). Methods of Soil analysis. Part 2. 2^{nd} Edition. Chemical and microbiological properties. American Society of Agronomy and Soil Science Society of America. Madison Wisconsin USA. pp. 301-312.

Nyarko P., Wontuo P., Nazzar A., Phillips J., Ngom P. and Binka F. 2008. Navrongo Demographic Survey System Ghana. Indepth Monograph. 1: 1-13.

Rafique M., Hussain A., Mahmood T., Alvi A.W. and Alvi M. B. 2004. Heritability and interrelationships among grain yield and yield components in maize (*Zea mays* L.). Int'l. J. Agric. and Biol. 6(6): 1113-1114.

Sipaseuth B. J., Fukai S., Farrell T. C., Senthonghae M., Sengkeo P. S., Linquist B. and Chanphengsay M. 2007. Opportunities to increasing dry season rice productivity in low temperature affected areas. Field Crops Res. 102: 87-97.

Thomas G. W. 1982. Exchangeable cations. In: Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.). Methods of Soil analysis. Part 2, Agron. Monograph 9, Am. Soc. of Agron. Madison Wisconsin. pp. 159-165.