Asian Journal of Agricultural and Horticultural Research

1(1): 1-12, 2018; Article no.AJAHR.39488

Effects of Nitrogen Fertilizer Rates and Soil Types on Yield and Yield Components of Maize (*Zea mays* L.) in Yola, Adamawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author JBA designed the study. Author IA performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JBA and IA managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAHR/2018/39488
Editor(s):
(1) Magdalena Valsikova, Professor, Department of Vegetables Production, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture (SUA), Nitra, Slovakia.
Reviewers:
(1) Leyla Idikut, Sutcu Imam Universty, Turkey.
(2) Clint Magill, Texas A&M University, USA.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/23261

Original Research Article

Received 10th December 2017
Accepted 14th February 2018
Published 21st February 2018

ABSTRACT

Aims: The experiments were carried out o determine the effects of different rates of nitrogen fertiliser and soil types on the yield and yield component of maize plant in Yola.
Duration and Place of Study: Field experiments were conducted during 2010, 2011 and 2012 cropping seasons at the Teaching and Research Farm, Modibbo Adama University of Technology Yola (Sandy-loam soil) and a private farm in Karewa area of Yola (Clay-loam soil).
Methodology: Treatments consisted of five levels of nitrogen fertiliser (0, 40, 80, 120 and 160 kg N/ha) applied as urea while phosphorus and potassium were maintained at 60 kg/ha each applied as single superphosphate and Muriate of potash on the sandy-loam and clay-loam soils. The experiments were laid out in a Randomized Complete Block Design (RCBD) replicated three times. Parameters measured include number of ears/plant, length of ears, ear diameter, number of grains

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per year, the weight of 100 grains, the weight of grains/ear and total grain yield. Data collected were subjected to analysis of variance (ANOVA) appropriate to RCBD using statistical package SAS for Windows Release 9.2 and Least Significant Difference (LSD) method was used to compare the difference between means.
Results: Regarding ear diameter, 100-grain weight and total grain weight, there were significant influences of rates of nitrogen fertiliser and soil types. The yield of maize was significantly affected by rates of nitrogen fertiliser and soil types. The highest yield of 5,330.6 kg/ha was obtained with 160 kg N/ha.
Conclusion: Based on the finding of the study, applying the rate of 160 kg N/ha on sandy-loam soil appeared to be promising for improved yield of maize in Yola and is, therefore, recommended to farmers in Yola.

Keywords: Nitrogen fertiliser; soil types; yield; yield components.

1. INTRODUCTION

Decline in soil fertility particularly in nitrogen levels on small-scale farms where a bulk of the maize are produced has resulted in crop yields falling to very low levels, and food insecurity is becoming real by the day. IITA [1] reported that throughout the tropics and subtropics, small-scale farmers grow maize, mostly for subsistence as part of agricultural systems that feature several crops and sometimes livestock production. Unlike the developed countries where hybrid varieties are commonly grown with high inputs using mechanised operations, the production systems in sub-Saharan Africa often lack inputs such as fertiliser, improved seed, irrigation and labour.

In the past two decades, maize has spread rapidly into the savannas, replacing traditional cereal crops such as sorghum and millet; particularly in areas with good access to fertilizer inputs and markets. In most West African moist savannas, higher radiation levels, lower night temperatures, and reduced incidence of diseases and insect pests have helped to increase maize yield potentials [2]. In spite of the increase in land areas under maize production, the yield is still low. Onasanya et al. [3] reported that the major causes of low maize yield are declining soil fertility and insufficient use of fertilizers resulting in severe nutrient depletion of the soil. Current productions of cereal grains particularly in sub-Saharan Africa is inadequate for supplying the nutritional demand of the rapidly growing African population. Sanchez et al. [4] linked the origin of declining per capita food production in sub-Saharan Africa to soil nutrient management and further noted that production would undoubtedly fail to meet the nutritional needs of African people unless issues within soil fertility are addressed. The failure to improve soil fertility and nutrient use efficiency has fuelled environmental degradation, food insecurity, and the need for outside aid. Rahimizadeh et al. [5] posited that nitrogen is often the limiting nutrient for crop yield in many regions of the world and it is the essential input for cereal production systems. The increase of agricultural food production worldwide over the past four decades has been associated with a seven-fold increase in the use of nitrogen fertilizer. Kogbe and Adediran [6] also reported that nitrogen is a vital plant nutrient and a major yield-determining factor required for maize production and its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. Rowland [7] and Kamara et al. [2] submitted that nitrogen is the most limiting nutrient in maize production in the savannas of West Africa. Initially, resource-poor farmers relied on shifting cultivation or bush-fallow for soil fertility management. However, because of increasing population pressure, there is an intensification of land use. As a result, nutrients and organic matter in the soil are depleted, and crop yield steadily decrease. Farmers in the savanna zone of northern Nigeria often apply the more significant amount of nitrogen fertilizer and organic manure because they recognize that they cannot grow maize without organic and inorganic nutrient inputs [8].

Edmonds et al. [9] reported that Sub Saharan Africa currently has a population approaching 800 million people. It is growing annually at an alarming rate of 19 million people per year. Feeding an additional 19 million people in a currently depressed society further compromises the effectiveness that over-stretched assistance agencies can deliver. While population has increased in sub-Saharan Africa in the last 10 years, nitrogen fertilizer consumption decreased over the same period. This is extremely disturbing since without nitrogen, protein simply cannot be produced.

2. MATERIALS AND METHODS

2.1 Experimental Sites

Field experiments were conducted at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola and a private farm in Karewa area of Jimeta-Yola which is 15 km from the University Teaching and Research Farm during the 2010, 2011 and 2012 cropping seasons. Yola is located between latitude $9^{o}10'$ to $9^{o}20'$N and longitude $12^{o}20'$ to $12^{o}35'$E. The experimental plots were located on latitude $9^{o}21.276'$ to $9^{o}21.281'$N and longitude $12^{o}30.189'$ to $12^{o}30.200'$E and latitude $9^{o}14.733'$ to $9^{o}14.738'$N and longitude $12^{o}26.250'$ to $12^{o}26.261'$E. In this environment, rainfall ranges between 556.1 mm – 786.90 mm commencing in early May with moisture peaking in August/September and terminating in late October. The soils in the experimental sites were clay loam and sandy loam classified as Typic Haplustalf.

2.2 Experimental Design and Treatments

Treatments consisted of five levels of Nitrogen fertilizer (Urea-46% N) applied at 0, 40, 80, 120 and 160 kg N/ha while phosphorus and potassium were maintained at 60 kg/ha each. The experiments were carried out in two different locations with distinct soil types for each location, one on a clay-loam soil located in Karewa Jimeta-Yola and the other on sandy-loam soil located at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola. The two experimental sites received the same nitrogen fertilizer treatments which were laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Raised seedbeds were prepared. The raised seedbeds were then marked out into plots; the sizes of each plot were 5m x 4m with a distance of 100 cm between the plots. The land area was 18m x 30m ($540m^2$). Sowing was done manually in the first week of July each year using pre-marked rope. Maize seed was sown at 3 – 4 seed/hole which was later thinned to one seedling/stand at 14 days after sowing.

2.3 Planting Material

Maize seed (Oba-98) is a hybrid variety produced by Premier Seeds Ltd. Zaria and was obtained from a commercial seed seller in Yola and used for the experiments.

2.4 Cultural Practices

Maize seed (Oba-98) was treated with apron plus against soil-borne diseases. The land was ploughed and leveling was done manually, after which raised seedbeds were prepared. Planting was done in the first week of July in the 2010, 2011 and 2012 cropping seasons. Weeds were controlled by application of pre-emergence herbicides. Split fertilizer applications were done at 14 days after sowing and teaseling stage.

2.5 Parameters Measured

Data collected for yield and yield parameters were recorded at 6 and 9 weeks respectively after sowing (WAS) and at harvest. Five plants were selected consecutively and marked from each of the plots, measurements were taken and then the means for number of ears per plant, length of ears, ear diameter, number of grains per ear, weight of 100 grains, weight of grains per plot and total grain yields were recorded. The total grains from all the plots were collected and the yield expressed in kg/ha was computed using the formula below:

Grain yield (kg/ha) =

$$\frac{\text{(Grain yield/plot)}}{\text{Net plot size } (20\text{m}^2)} \text{ X } \frac{10{,}000\text{m}^2}{1}$$

2.6 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using a statistical package SAS for Windows Release 9.2 (SAS Institute) [10]. Least Significant Difference (LSD) method was used to assess the differences among means.

3. RESULTS

3.1 Effects of Nitrogen Fertilizer Rates and Soil Types on Number of Ears per Plant

Results of the effects of nitrogen fertilizer rates and soil types on number of ears per plant in 2010, 2011 and 2012 cropping seasons are presented in Table 1. The effects of soil types on number of ears per plant showed that there were no significant differences (P≤0.05). Similarly, the effect of nitrogen fertilizer rates on number of ears per plant also revealed that there was no significant effect (P≤0.05) in the 2010, 2011 and 2012 cropping seasons. All the plants that received different nitrogen fertilizer rates produced slightly more than one ear per plant.

3.2 Effects of Nitrogen Fertilizer Rates and Soil Types on Length of Ears

Results of the effects of nitrogen fertilizer rates and soil types on length of ears in 2010, 2011 and 2012 cropping seasons are presented in Table 1. The effects of soil types on length of ears in 2010, 2011 and 2012 cropping seasons showed that there were highly significant differences (P≤0.01) in all the three cropping seasons. In 2010 cropping season, longer ears were obtained on clay-loam soils which produced ears of 14.34 cm while sandy –loam soils had ears that were 13.5 cm. In 2011 cropping season, longer ears were obtained on sandy – loam soil (14.85 cm) while clay-loam soils produced ears of 14.33 cm length. A similar trend was also obtained in 2012 cropping seasons where longer ear lengths were obtained on sandy-loam soil with value of 14.9cm while a value of 14.68 cm was obtained on clay-loam soil.

The effects of nitrogen fertilizer rates on length of ears in 2010, 2011 and 2012 cropping seasons showed a highly significant effect (P≤0.01). In 2010 cropping season, the application of 160kg N/ha produced a longer ear length (16.90cm), followed by 120 kg N/ha with 15.48cm ear length. The application of 80kg N/ha produced ear length of 14.78 cm.

The lower values of 13.38 and 9.98 cm were obtained from the application of 40 and 0 kgN/ha respectively in 2010 cropping season. The application of 160 kg N/ha produced ears that were longer (16.45cm), followed by 120kg N/ha with 16.16 cm, 80 kg N/ha produced ears of 14.93cm. Lower values of 13.68 and 11.73 cm ear length were obtained with the application of 40 and 0 kg N/ha respectively in 2011.

In 2012 cropping season, the effects of nitrogen fertilizer rates on length of ears was highly significant (P≤0.01). The longest ear was obtained with 160kg N/ha application which produced ear length of 16.03cm, which was followed by 15.98 cm with 120kg N/ha application. The application of 80kg N/ha produced ear length of 14.50cm. The application of 40 and 0 kg N/ha produced ear lengths of 14.30 and 12.10cm, respectively. In every three years, the increase of fertilizer dose increased the length of the ear. Higher rates of nitrogen fertilizer produced longer ears.

Table 1. Effect of soil types and nitrogen fertilizer rates on number of ears/plant and length of ears (cm) in 2010, 2011 and 2012 cropping seasons

Factors	Number of ears/plant			Length of ears		
	2010	2011	2012	2010	2011	2012
Soil type						
Clay-loam	1.30	1.33	1.33	14.34	14.33	14.68
Sandy-loam	1.26	1.40	1.26	13.50	14.85	14.90
Mean	1.26	1.36	1.29	13.92	14.59	14.79
Prob. of F	0.12	0.13	0.11	0.01	0.01	0.01
LSD	0.35	0.39	0.38	0.66	0.57	0.31
Fertilizer rates (Kg N/ha)						
0	1.00	1.00	1.16	9.98	11.73	12.10
40	1.16	1.33	1.00	13.38	13.68	14.30
80	1.33	1.33	1.33	14.78	14.93	15.50
120	1.50	1.50	1.50	15.48	16.16	15.98
160	1.50	1.66	1.50	16.00	16.45	16.03
Mean	1.30	1.36	1.30	13.98	14.59	14.78
Prob. of F	0.11	0.13	0.11	0.01	0.01	0.01
LSD	0.55	0.63	0.60	1.05	0.90	0.49

LSD = Least significant difference

3.3 Effects of Nitrogen Fertilizer Rates and Soil Types on Ear Diameter

The effects of nitrogen fertilizer rates and soil types on ear diameter for the 2010, 2011, and 2012 cropping seasons are presented on Table 2. Results on the effects of soil types on ear diameter showed highly significant differences ($P \le 0.01$) in 2010 cropping seasons and significant effects ($p \le 0.05$) were recorded in 2011 and 2012 cropping seasons. In 2010 cropping season, higher values were obtained on clay-loam soil, which gave ear diameter of 2.70cm, and sandy-loam soil produced ear diameter of 2.06 cm. A similar trend was recorded in 2011 cropping season where higher values were obtained on clay-loam soil with a value of 2.7 cm while 2.12 cm was obtained on sandy-loam soil. The same trend was maintained in 2012 cropping season but much higher values were obtained on clay- loam soil, ear diameter of 3.35 cm was recorded while 2.88 cm was obtained on sandy-loam soil.

The effects of nitrogen fertilizer rates on ear diameter for the 2010, 2011 and 2012 cropping seasons showed that effects were highly significant ($P \le 0.01$) in 2010 cropping season, and significant differences ($P \le 0.05$) were observed in 2011 and 2012 cropping seasons. In 2010 cropping season, the application of 160kg N/ha produced the highest (3.10 cm) ear diameter. The lowest ear diameter value of 1.60 cm was recorded with 0 kg N/ha.

3.4 Effects of Nitrogen Fertilizer Rates and Soil Types on Number of Grains/Ear

The results of the effects of nitrogen fertilizer rates and soil types on number of grains per ear in 2010, 2011 and 2012 cropping seasons are presented in Table 3. The effects of soil types on number of grains per ear revealed highly significant effects ($p \le 0.01$) in 2010, 2011 and 2012 cropping seasons. In 2010 cropping season, the application of 160 kg N/ha produced ears with the highest number of kernels (580 grains), this was followed by 120 kg N/ha which produced 560 grains per ear. Application of 120 kg N/ha produced 527 grains per ear which was followed by 467 grains per ear with 80 kg N/ha. Lower grain number per ear was obtained with the application of 40 and 0 kg N/ha which produced 417 and 265 grains per ear respectively. In 2012 cropping season, the situation changed where the highest number of grains per ear was obtained with 120 kg N/ha which gave 534 grains per ear, which was followed by 522 grains per ear with 160 kg N/ha application. Expectedly, lower values of 419 and 261 grains per ear were recorded with 40 and 0 kg N/ha applications, respectively.

Table 2. Effect of soil types and nitrogen fertilizer rates on diameter of ears and in 2010, 2011 and 2012 cropping seasons (cm)

Factors	Diameter of ears		
	2010	**2011**	**2012**
Soil type			
Clay-loam	2.70	2.70	3.35
Sandy-loam	2.06	2.12	2.88
Mean	2.38	2.41	3.11
Prob. of F	0.01	0.03	0.02
LSD	0.17	0.13	0.17
Fertilizer rates (Kg N/ha)			
0	1.60	1.73	2.53
40	2.15	2.16	2.81
80	2.28	2.48	3.18
120	2.76	2.71	3.40
160	3.10	2.98	3.66
Mean	2.38	2.41	3.11
Prob. of F	0.01	0.03	0.02
LSD	0.27	0.20	0.27

LSD = Least significant difference

Table 3. Effect of soil type and nitrogen fertilizer on number of grains/ear in 2010, 2011 and 2012 cropping seasons

Factors	Number of grain/ear		
	2010	**2011**	**2012**
Soil type			
Clay-loam	452.0	421.4	407.0
Sandy-loam	504.6	486.5	491.2
Mean	478.3	453.9	449.1
Prob. of F	0.01	0.01	0.01
LSD	25.77	30.75	39.10
Fertilizer rates (Kg N/ha)			
0	309.8	265.1	261.3
40	424.5	417.8	419.1
80	517.1	467.5	508.6
120	560.1	527.5	534.1
160	580.0	591.8	522.3
Mean	478.3	453.9	449.1
Prob. of F	0.01	0.01	0.01
LSD	40.75	48.62	61.82

LSD = Least significant difference

3.5 Effects of Nitrogen Fertilizer Rates and Soil Types on 100 Grains Weight

The effects of Nitrogen fertilizer and soil types on 100 grains weight in 2010, 2011 and 2012 cropping seasons are presented in Table 4. Results on the effects of soil types on 100 grains weight in 2010, 2011 and 2012 cropping seasons showed that there was a significant effect ($P \leq 0.05$). In 2010 cropping season, the weight of 100 grains on clay-loam soil gave higher value (28.7 g) while those on sandy-loam soil was 24.97 g. Similar trend was maintained in 2011 cropping season where the weight of 100 grains produced on clay-loam soil was 28.17 g while 100 grains produced on sandy-loam soil was 24.67 g. A slightly higher value were obtained in 2012 cropping seasons, where the weight of 100 grains produced on clay-loam soil had a value of 30.19 g while those on sandy-loam soil was 29.14 g.

Table 4. Effect of soil types and nitrogen fertilizer rates on weight of 100 grains in 2010, 2011 and 2012 cropping seasons (g)

Factors	Weight of 100 grains		
	2010	**2011**	**2012**
Soil type			
Clay-loam	28.70	28.17	30.19
Sandy-loam	24.97	24.67	29.14
Mean	26.84	26.42	29.66
Prob. of F	00.01	0.03	0.05
LSD	3.25	2.70	2.06
Fertilizer rates (Kg N/ha)			
0	23.43	22.16	22.90
40	26.03	27.06	28.91
80	27.21	23.85	29.70
120	28.05	28.50	34.16
160	29.45	30.53	32.66
Mean	26.83	26.42	29.66
Prob. of F	0.04	0.02	0.03
LSD	5.15	4.28	3.26

LSD = Least significant difference

The effects of nitrogen fertilizer rates on weight of 100 grains in 2010, 2011 and 2012 cropping seasons showed significant effects ($P \leq 0.05$). In 2010 cropping season, the application of 160kg N/ha produced grains that were weightier with a value of 29.45 g, followed by 28.05 g with the application of 120kg N/ha. The weight of 100 grains found on plots applied 80 kg N/ha had a value of 27.21 g. The lower weight values of 26.03 and 23.43 g were obtained with 40 and 0 kg N/ha application. In 2011 cropping season, a slight variation was observed. The highest value of 30.53 g for 100 grains was found with the application or 160 kg N/ha, which was followed by the value of 28.5 g with the application of 120 kg N/ha. This value was followed by 27.06 g with the application of 40 kg N/ha. The application of 80 kg N/ha gave a lower weight value for 100 grains with 23.85 g while the lowest value of 22.16 g was obtained with 0 kg N/ha. A completely different result was obtained in 2012 cropping season where the application of 120kg N/ha gave the highest value of 34.16 g for 100 grains which was followed by 32.66 g with 160 kg N/ha. The application of 80 kg N/ha gave the value of 29.7 g for 100 grains. The lowest values of 28.91 and 22.9 g was obtained with the application of 40 and 0 kg N/ha respectively.

3.6 Effects of Nitrogen Fertilizer Rates and Soil Types on Total Grains Weight per Plot

The effects of nitrogen fertilizer rates and soil types on total grains weight per plot in 2010, 2011 and 2012 cropping seasons are presented in Table 5. Results on the effects of soil type on total grains weight per plot showed that there was a significant effect (≤ 0.05) in 2010 cropping season and highly significant effects ($P \leq 0.01$) in 2011 and 2012 cropping seasons. In 2010 cropping season, the result showed that higher weight value was recorded on clay-loam soils which gave 7.22kg while the grains weight per plot on sandy-loam soil was 6.16 kg. In 2012 cropping season, the total grains weight per plot on clay-loam soil was 6.28kg and 5.00kg on sandy-loam soil. The results showed that the total grains weight per plot was higher consistently in 2010, 2011 and 2012 cropping seasons on clay-loam soil.

Results on the effects of nitrogen fertilizer on total weight of grains per plot showed that there was a highly significant effect ($P \leq 0.05$) in 2011 cropping season. In 2010, cropping season, results showed that the application of 120 kg N/ha produced 7.41 kg which was the highest grain weight per plot. This was followed by 7.18 kg with the application of 160 kg N/ha. The total weight 6.78 kg was recorded with the application of 40 kg N/ha. Lower weight values of 6.75 and 5.31 kg were recorded with 80 and 0 kg N/ha. In 2011, cropping season, the result was slightly different from the one recorded in 2010 cropping season. The highest grain weight per plot was recorded with the application of 160 kg N/ha which produced 6.61 kg of grain weight, followed by 5.80 kg obtained with 120 kg N/ha. Application of 80 kg N/ha gave 5.73 kg while 40kg N/ha produced 5.26 kg. The lowest kernel weight value of 3.68 kg was recorded with 0 kg N/ha. A similar trend was maintained in 2012 cropping season but with slightly different values. The application of 160 kg N/ha produced grain weight of 6.60 kg which was followed by 6.45 kg with 120 kg N/ha.

3.7 Effects of Nitrogen Fertilizer Rates and Soil Types on Total Grains Yield

The effects of nitrogen fertilizer rates and soil types on total grain yield for the 2010, 2011 and 2012 cropping seasons are presented in Table 6. Results on the effects of soil types on the total grain yield showed that there were highly significant effects ($P \leq 0.01$) in 2010, 2011 and 2012 cropping seasons. In 2010 cropping season, a grain yield of 5285 kg was recorded on sandy – loam soil while 5185 kg was obtained on clay-loam soil. A similar trend was recorded 2011 cropping season but with slightly lower values. 5002.6 kg were recorded on sandy-loam soil while a grain yield of 4902.2 kg/ha was recorded on clay – loam soil. In the 2012 cropping season, sandy-loam soil produced higher yield value of 4908.8 kg/ha while 4531.9 kg/ha was recorded on clay-loam soil. Sandy-loam soil recorded higher grain yield consistently in the 2010, 2011 and 2012 cropping seasons. Results of the effects of the nitrogen fertilizer rates on total grain showed that there was a highly significant effect ($P \leq 0.01$) in 2010, 2011 and 2012 cropping seasons. In 2010 cropping season, the application of 160 kg N/ha produced the highest grain yield which was 5288.1kg/ha. The application of 120kg N/ha recorded a grain yield of 4066.6 kg/ha. However, the application of 40 kg N/ha produced a grain yield of 4850.1 kg/ha which was higher than the values obtained with the application of 120 and 80 Kg N/ha. In 2011 cropping season, the result was different from the one obtained in 2010 cropping season. The application of 160 kg N/ha produced the highest grain yield of 5015.3 kg/ha, followed by 4908.1 kg/ha recorded with the application of 120 kg N/ha. The application of 80 kg N/ha produced a grain yield of 4888.8 kg/ha. Lower grain yield of 4503.3 and 1350.8 kg/ha was recorded with the application of 40 and 0 kg N/ha respectively. In 2012 cropping season, similar trend to that of 2011 cropping season was observed, the application of 160 kg N/ha gave a grain yield of 5330.6 kg/ha, followed 5076.6 and 5003.8 kg/ha with the application of 120 and 80 kg N/ha respectively. The application of 40 kg N/ha gave a grain yield of 3983.8 kg while the lowest grain yield of 1950.3 kg/ha was recorded with the application of 0 kg N/ha.

Table 5. Effect of soil types and nitrogen fertilizer rates on weight of grains/plot in 2010, 2011 and 2012 cropping seasons (kg)

Factors	Weight of grains/plot		
	2010	**2011**	**2012**
Soil type			
Clay-loam	7.22	5.78	6.28
Sandy-loam	6.16	5.06	5.00
Mean	6.69	5.42	5.64
Prob. of F	0.03	0.01	0.01
LSD	0.46	0.44	0.48
Fertilizer rates (Kg N/ha)			
0	5.31	3.68	3.88
40	6.78	5.26	5.30
80	6.75	5.73	5.96
120	7.41	5.80	6.45
160	7.18	6.61	6.60
Mean	6.68	5.42	5.64
Prob. of F	0.01	0.03	0.01
LSD	0.72	0.70	0.76

LSD = Least significant difference

Table 6. Effect of nitrogen fertilizer rates and soil type on total grain yield for 2010, 2011 and 2012 cropping seasons (kg/ha)

Factors	Total grain yield		
	2010	**2011**	**2012**
Soil type			
Clay-loam	5185.0	4902.2	4531.9
Sandy-loam	5285.0	5002.6	4908.8
Mean	5235.0	4952.4	4720.0
Prob. of F	0.01	0.01	0.01
LSD	108.70	111.20	102.50
Fertilizer rates (Kg N/ha)			
0	1750.0	1350.8	1950.3
40	4850.1	4503.3	3983.8
80	4050.7	4888.8	5003.8
120	4066.6	4908.1	5076.6
160	5288.1	5015.3	5330.6
Mean	4001.1	4133.3	4269.0
Prob. of F	0.01	0.01	0.01
LSD	127.90	131.50	121.70

LSD = Least significant difference

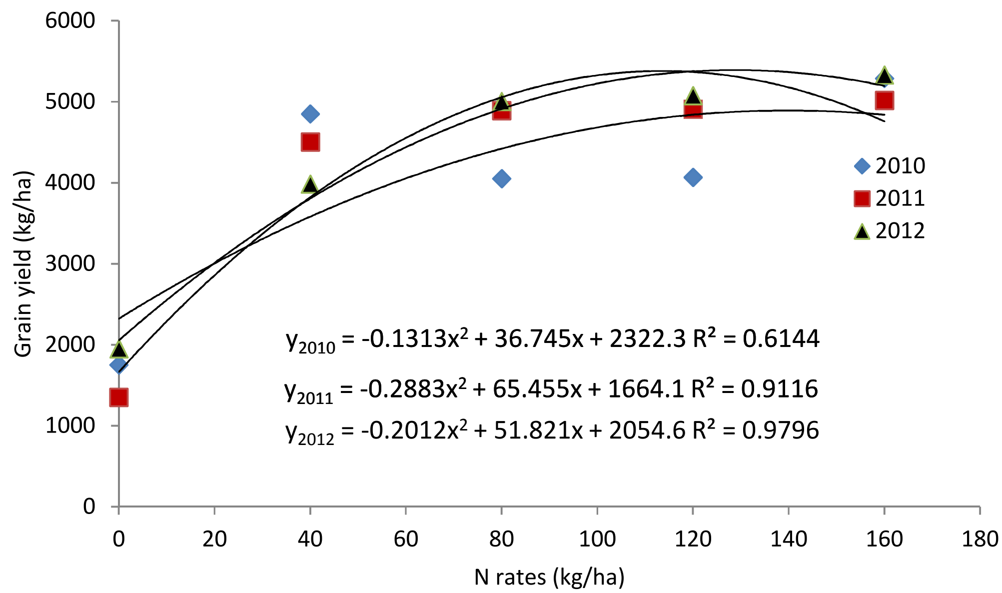

Fig. 1. Trend analysis for grain yield for 2010, 2011 and 2012 cropping

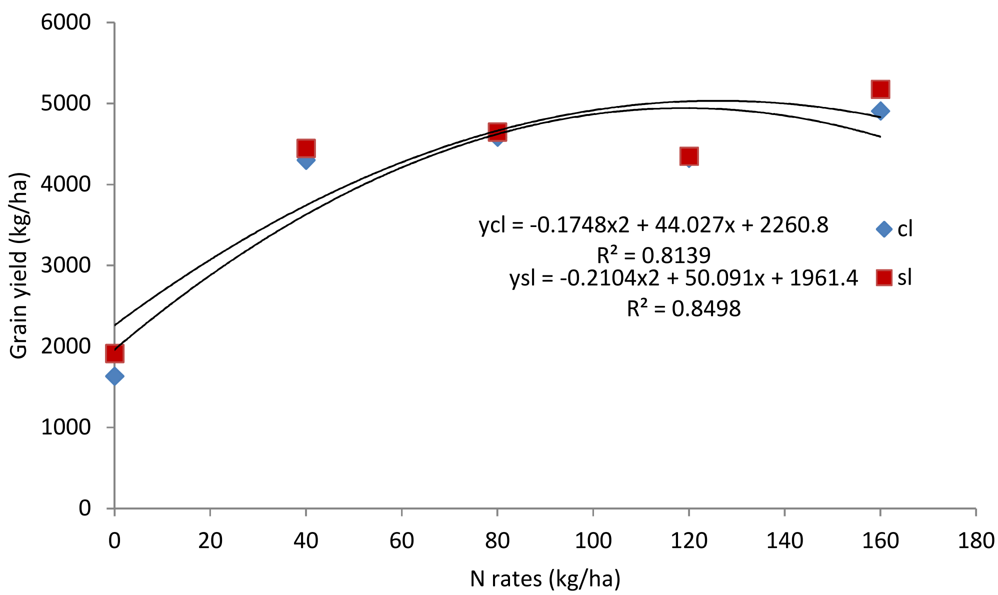

Fig. 2. Trend analysis for grain yield on clay-loam and sandy-loam soils

Data on total grain yield of maize were separated on yearly basis and regressed (Fig. 1). All the regressions were highly significant ($P \leq 0.01$) while the degree of relationship (R^2) between the years and nitrogen fertilizer rates were 0.61, 0.91 and 0.97 for 2010, 2011 and 2012 cropping seasons respectively. This showed that yield had a positive regression over time. Similarly, 0.81 and 0.84 were the degree of relationship between clay-loam and sandy-loam soils; in relation to the nitrogen fertilizer rates (Fig. 2). Under fertilized condition, the intercept and the regression line could be used for yield prediction.

4. DISCUSSION

Nitrogen fertilizer rates and soil types significantly influenced the yield and yield components of the maize plants in all the cropping seasons. Nitrogen is a component of many biological compounds that plays a major role in photosynthetic activity and crop yield capacity, and its deficiency constitutes one of the major yield limiting factors for cereal production especially maize. Yield components in terms of length of ears were significantly influenced by rates of nitrogen fertilizer and soil types. This was because nitrogen encourages dry matter production in the maize plant, which has a positive influence on the final grain yield. This finding was similar to that reported by Hokmalipour et al. [11] which stated that increased nitrogen fertilizer rates led to significant increase in ear length. Generally, ear diameter decreased with decrease in nitrogen rates and increased with nitrogen fertilizer application. A similar result was also reported by El-Sheikh [12] who reported that applying 160 kg N/ha significantly increased ear characters and grain yield. This result also agrees with the report of Altieiri [13] who stated that the diameter of the ear is proportional to the uptake of nitrogen fertilizer by the maize plant. Therefore, the dry matter production of the maize plant depends on the amount of nitrogen fertilizer available to it. There was a significant influence of rates of nitrogen fertilizer and soil types on the number of kernels per ear. The number of kernels increased with increased nitrogen application, which is also consistent with the report of Hokmalipour et al. [11] which stated that nitrogen has significant effects on the grain yield of maize as a result of increase in the number of kernels per ear. Similar result was also reported by Jaliya et al. [14] who opined that increased nitrogen fertilizer rates increased the number of kernels per ear. This was attributed to nitrogen being part of the essential nutrients required for the promotion of the meristematic and physiological activities such as plant leaf spread, root development and plant dry matter production leading to an efficient absorption and translocation of water and nutrients, interception of solar radiation and assimilation of carbon dioxide. These activities promotes higher photosynthetic activities leading to the production of enough assimilates for subsequent translocation to the various sinks and hence the production of higher yield and yield components of maize. It is therefore evident that an increased number of kernels per ear will lead to increase in the overall grain yield.

The weight of 100 grains was significantly influenced by rates of nitrogen fertilizer. Increase in nitrogen levels increased the weight of grain. This was because nitrogen plays a key role in metabolism and dry matter production of the maize plant. It mediates the utilization of potassium and other elements in the soil. One hundred grains weight was not influenced by soil types. As an extreme example reported by Hay and Walker [15], and Rowland [7], a heavily fertilized maize plant, whose canopy senesces rapidly after anthesis because of drought or dry spell, could give a reasonable overall grain yield but which was made up of a large number of very light grains. It is evident therefore that nitrogen plays a very important role in the weight of the maize kernel. The weight of individual kernel is influenced by the amount of nitrogen utilized by the plant especially during the period of kernel setting.

Grain yield is the main target of crop production. Grain yield was significantly affected by both nitrogen fertilizer rates and soil types in all the cropping seasons. Nitrogen rates significantly increased the grain yield. This is attributable to the ability of the maize plant to utilize the available nutrient to produce and partition more assimilates to the various sinks leading to the production of higher yields. Similar findings was reported by Jaliya et al. [14] who observed that increase in nitrogen fertilizer rate increased the grain yield of maize because the nitrogen fertilizer promoted higher photosynthetic activities leading to production of enough assimilates for subsequent translocation to the various sinks and hence the production of higher yields. As far as crop physiology is concerned, Hay and Walker [15] reported that nitrogen fertilizer influences cereal crops in many ways, increased nitrogen supply, through its effects upon leaf size and longevity results in increases in the size and duration of the crop canopy, these increases resulted in higher rates of crop dry matter production. Therefore, there is a strong link between crop nitrogen uptake and dry matter production.

Grain yield of maize increased with increase in nitrogen fertilization. This was because nitrogen was completely depleted in the soil. There was a marked response of yield to any increment in nitrogen fertilizer. This agrees with Hatfield and Prueger [16] who revealed that maize production continues to increase with increasing nitrogen application. Grain yield of maize may increase with corresponding increase in nitrogen fertilization to a certain limit, beyond which there may be a drop in yield even with increment in nitrogen fertilizer application. Hatfield and

Prueger [16] also reported that maize yield across nitrogen fertilizer rates and soil types showed an interesting pattern. Not surprising was the large increase in yield with addition of nitrogen above 56 kg N/ha, however, what was surprising was the decrease in the mean yield at rates above 116 kg N/ha.

An economic use of nitrogen will definitely improve yield of maize especially in the Guinea savanna where soil fertility management is very poor. Grain yield was consistently low on plots without nitrogen fertilization. This finding agrees with that of Rowland [7] who observed that maize fails to produce worthwhile grain yields on plots without fertilizer. Increased nitrogen fertilizer application even beyond 160 kg N/ha in Guinea savanna can lead to higher yields. This finding is consistent with the report of Singh et al. [17] who submitted that the application of 200 kg N/ha increased the yield of maize. Consequently, a higher rate of nitrogen fertilizer is required in areas where there is low inherent soil fertility especially of nitrogen.

5. CONCLUSION

From the result of this study, it could be concluded that nitrogen fertilizer rates and soil types have significant influence on yield and yield components of the maize plant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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