Original Research Article

Nitrogen Use Efficiency in Maize (*Zea mays* L.) as Affected by Rates of Nitrogen Fertilizer Application on Different Soil Types in Yola, Adamawa State, Nigeria

ABSTRACT

The experiments were carried out to determine the influence of rates of nitrogen fertilizer application on different soil types that will ensure highest nitrogen use efficiency in the maize plant in Yola. Field experiments were conducted during the 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). Treatments consisted of five levels of nitrogen fertilizer (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 included; nitrogen accumulation/plant, nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen use efficiency. Data collected were subjected to analysis of variance (ANOVA) appropriate to RCBD and Least Significant Difference (LSD) method was used to compare the difference between means. Nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen use efficiency were significantly increased by rates of nitrogen fertilizer and soil types. The highest Nitrogen use efficiency of 72.1% was recorded on sandy-loam soil with the application of 120 kg N/ha. Sandy-loam soil has a good air and moisture retention capacity that encourages optimal and healthy maize growth when compared to clay-loam soil. Based on the findings of the study, applying the rate of 120 kg N/ha on sandy-loam soil appeared to be promising for increased nitrogen use efficiency in the maize plant and improved yield of maize in Yola and is therefore recommended to farmers in Yola.

Key words: *nitrogen use efficiency, nitrogen fertilizer, soil types*

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in sub-Saharan Africa [1] and it is one of the most important staple foods in Africa accounting for up to 70% of the total human caloric intake [2]. Based on area of production, maize is the third most important cereal crop after wheat and rice in the world [3]. Maize is high yielding, affordable and easily digestible. Grains, ears, stalks and tassel are used for both food and non-food products.

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 mechanized operations, the production systems in sub-Saharan Africa often lack inputs such as fertilizer, 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 spite of the increase in land area under maize production, yield is still low. Onasanya *et al.* [4] reported that the major causes of low maize yield are declining soil fertility and insufficient use of fertilizers resulting in severe nutrient depletion of soil. Current production of cereal grains particularly in sub-Saharan Africa is inadequate for supplying the nutritional demand of the rapidly growing African population. Sanchez *et al.* [5] linked the origin of declining per capita food production in sub-Saharan Africa to soil nutrient management and further noted that production will 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. Worku *et al.* [6] reported that in most cases Nigerian farmers use less than 20 kg N/ha for maize crop because farmers lack access to fertilizer or do not have the cash to buy the input. It means that farmers must make good use of the small amount of fertilizer they get to boost productivity. There is the need to improve maize productivity in areas with low nitrogen fertility especially in the savanna agro-ecology.

One strategy for improving the productivity of maize under suboptimal nitrogen fertility is to enhance efficiency in nitrogen use. USDA [7] suggested that an application schedule that applies a small amount of nitrogen early in the season (pre-planting) followed by later in-season application of higher amounts of nitrogen is ideal. This schedule takes care of the small, but important early season nitrogen needs and maximizes uptake by applying nitrogen during the rapid growth and nitrogen requirement period.

Limited supplies of nitrogen, the continual rise in prices and elevated economic risk of nitrogen fertilization, combined with the existing low yield levels of cereal production systems reiterates the importance of nitrogen use efficiency (NUE). Kamara *et al.* [8] defined Nitrogen Use Efficiency as grain production per unit of nitrogen available in the soil. Efficient use of nitrogen in plant production is an essential goal in crop management. Despite the widespread cultivation of maize by smallholder farmers in Adamawa State, yields from smallholder farms are very low owing to low soil fertility especially low nitrogen, lack of access to fertilizer or farmers do not have the financial resource to buy the input due to their low incomes hence the need to adopt a new management technique based on nitrogen use efficiency (NUE) which will enhance the ability of small-scale farmers to efficiently produce food and fibre for the growing population in Nigeria and in Adamawa State particularly.

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 respectively. In this environment, rainfall ranges between 556.1 and 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. The site at the Modibbo Adama University Teaching and Research Farm had previously been subjected to sorghum and maize cultivation while the Karewa site had maize and cowpea grown on it for five years.

2.2 Land Preparation, Experimental Design and Treatments

The land was ploughed and leveling was done manually, after which raised seedbeds were prepared. The raised seedbeds were then marked out into plots; the size of each plot was 5 x 4 m with a distance of 100 cm between the plots. The land area was 18 x 30 m (540 m^2). The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. 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 nitrogen fertilizer was applied in two splits, the first one at 14 days after sowing and the second at tasselling stage. 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 size of each plot was 5 x 4 m with a distance of 100 cm between the plots. The land area was 18 x 30 m (540 m^2).**

Maize seed (Oba-98), which is a hybrid variety produced by Premier Seeds Ltd. Zaria was obtained from a commercial seed seller in Yola and used for the experiments. The hybrid variety is early maturing, medium in height and grows between 0.90 – 1 m.

Maize seed (Oba-98) was treated with apron plus against soil-borne diseases. Sowing maize seed was done manually in the first week of July each year using pre-marked rope, and **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), which is a hybrid variety produced by Premier Seeds Ltd. Zaria was obtained from a commercial seed seller in Yola and used for the experiments. The hybrid variety is early maturing, medium in height and grows between 0.90 – 1 m.~~

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.** Weeds were controlled by application of pre-emergence herbicides. **Split fertilizer applications were done at 14 days after sowing and at tasselling stage.**

2.35 Collection of SoilPlant and PlantSoil Samples

Soil samples were collected from the experimental sites at the depths 0 – 30, 30 – 60 and 60 – 90 cm before sowing. **The soil samples were taken** and at three, six and nine weeks after sowing. The soil samples were air-dried and passed through 2 mm sieve to remove large particles, debris and stones.

Comment [SSR1]: Was it not too late for maize plants to make use of the nutrient applied? That's the question that will always come into the mind of whoever will read this publication.

The samples were then transferred to the laboratory for analysis to determine the nitrogen content of the soil. Destructive samplings of plants were carried out at 21 day intervals coinciding with the soil sampling periods to determine nitrogen content of the above ground biomass**dry matter**. Therefore, destructive samplings was **were** carried out at three, six and nine weeks after sowing. The samples were cut at ground level from the plots and then taken to the laboratory to determine the nitrogen content of the above ground biomass**dry matter**.

2.46 Extraction of Nitrogen from Soil and Plant Samples

Nitrogen was extracted from dried soil samples in the laboratory. The soil samples were digested with 15 ml nitric acid (HNO_3), 2 ml of perchloric acid, 15 ml hydrofluoric acid and 0.5 g $CuSO_4.5H_2O$ as catalyst was added and heated at 85 ^{0}C for three hours. It was then filtered, 100 ml of distilled water was added to the digest and 100 ml of 40% NaOH was also added to the digest and anti-bumping granules of zinc were added in a round bottom flask for distillation. 25 ml of boric acid cum indicator in a flat bottom flask (500 ml) was placed below the condenser of distillation assembly so that the lower open end of the condenser was dipped in solution. The distillation was carried out and 150 ml of distillate in the flask was titrated against 0.1 N HCl. From blue colour to light brown pink indicated the end point. Similarly, blanks were treated in the same manner.

% Nitrogen was calculated using the formula below:

$$\%N = \frac{T_1\ T_2 \text{ x N x } 1.4}{W}$$

Where T_1 = volume of titrate used against sample

T_2 = volume of titrate used against blank

N = normality of titrate (0.1 N) HCl

W = weight of soil sample used (g)

Plant samples **from the plots were collected to determine above ground dry matter accumulation. Plants were cut at ground level and** oven dried, weighed and milled to pass through a 1 mm mesh. Total nitrogen accumulated in each fraction was calculated as the product of nitrogen concentration (dry weight basis).

2.57 Data CollectionParameters Measured

Data collection started ~~at~~ one week after sowing (WAS). Data ~~collected~~ for growth and yield parameters were then recorded at three, six and nine 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 were recorded.

2.57.1 Nitrogen uptake efficiency

This was calculated using the formula described by Moll *et al.* [9] as follows:

$$\text{N-uptake efficiency} = \frac{\text{N (g N}_t\text{) at N rate applied} - \text{N (N}_t\text{) at 0 kg N ha}^{-1}}{\text{N applied (g N}_f\text{)}}$$

Comment [SSR2]: What is the sign found between T1 and T2 in the equation? Is it multiplication, addition or subtraction?

Comment [SSR3]: 1.".. in each fraction" This is not clear. Which fraction are you talking about? Each fraction or plot?
2. "Product of nitrogen concentration" Mathematically, a product is got by multiplying two values? Which ones are you referring to in this statement?

Comment [SSR4]: Growth and yield parameters that were measured should be given here. Describe how measurement of each parameter was done. This is to enable another researcher who repeats this experiment to be guided exactly what to do.

Where $(g\ N_t)$= Total N in above ground biomass

$(g\ N_f)$ = Amount of N applied

2.75.2 Nitrogen utilization efficiency

This was calculated using the formula described by Moll *et al.* [9] as follows:

$$\text{N-utilization efficiency} = \frac{\text{Grain yield (g/plant) at N rate applied} - \text{grain yield at 0kg N ha}^{-1}}{\text{N }(g\ N_t)\text{ at rate applied} - \text{N }(g\ N_t)\text{at 0kg ha}^{-1}}$$

Where $(g\ N_t)$= Total N in above ground biomass

$(g\ N_f)$= Amount of N applied

2.75.3 Nitrogen use efficiency

This was calculated according to Moll *et al.* [9] as follows:

$$\text{NUE} = \frac{\text{Grain yield (g/plant) at N rate applied – Grain yield at 0 kg N ha}^{-1}}{\text{N applied }(g\ N_f)}$$

Where $(g\ N_f)$= Amount of N applied

2.68 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 at 5 % level of significance was used to assess the differences among means.

Comment [SSR5]: At what level of significance were the means considered significantly different? I have inserted changes by assuming that it was 5%, and thus $LSD_{(0.05)}$. But adjust to the correct one, for example 1% if my assumption is wrong.

3. RESULTS

3.1 Physical and Chemical Properties of the Soil in the Study Sites

The physical and chemical characteristics of the soil at the study sites are presented in Table 1. Plots in the clay-loam site contained some sand sizes in the 0 - 40 cm depth but high clay content in the 60 – 80 cm depth. The sandy-loam plots contained low clay content in the 0 – 40 cm depth and very high clay content (727 g/kg) at the 80 cm depth. Textural fractions were intermediate in the 40 – 80 cm depth range for both clay-loam and sandy-loam soils. On the clay-loam soil, the initial nitrogen content at 20 cm depth was 3.5 mg/kg and at the 40 cm depth, the initial nitrogen content was 3.8 mg/kg. There was an increase in the initial nitrogen content at the 60 and 80 cm depth with the values of 11.5 and 30.6 mg/kg respectively. On the sandy-loam soil, the initial nitrogen content at the 20 cm depth was 2.0 mg/kg and at the 40 cm depth, it was 2.8 mg/kg. The situation changed at the 60 and 80 cm depth with the values of 14.0 and 37.0 mg/kg respectively.

Comment [SSR6]: In your methodology (Sections 2.3 and 2.4 above), the soil samples were analyzed for nitrogen ONLY. Then where did you get data for bulk density, particle density and soil water content presented in Table 1? These other parameters need to be described in the methodology.

Water retention and hydraulic conductivity for clay-loam soil showed higher value of 0.45 m^3m^{-3} while sandy-loam soil showed lower values of 0.35 m^3m^{-3}. Initial soil nitrogen content showed a very low residual nitrogen level especially in the 0 – 40 cm depth but the residual nitrogen level increased from 14.0 to 37.0 mg/kg at the 60 – 80 cm depth in both the clay-loam and sandy-loam soils.

Table 1. Soil Physical and Chemical properties of Clay-loam and Sandy-loam Plots

Depth (cm)	Bulk density (mg m^{-3})	Particle density			Water content at different pressure levels (kpa)						Initial N-content
		Sand	Silt (g kg^{-1})	Clay	1	10	40	100 m^3m^{-3}	100	1500	mg kg^{-1}
Clay-loam soil											
20	1.53	293	168	539	0.43	0.39	0.38	0.35	0.31	0.27	3.5
40	1.51	48	275	677	0.42	0.40	0.38	0.36	0.34	0.31	3.8
60	1.52	66	241	693	0.45	0.45	0.41	0.40	0.38	0.34	11.5
80	1.57	32	164	804	0.45	0.43	0.41	0.39	0.37	0.34	30.6
Sandy-loam soil											
20	1.55	869	58	73	0.35	0.23	0.21	0.09	0.07	0.06	2.0
40	1.51	738	120	142	0.32	0.24	0.22	0.17	0.14	0.12	2.8
60	1.54	503	209	288	0.41	0.30	0.29	0.25	0.21	0.16	14.0
80	1.44	67	206	727	0.44	0.42	0.41	0.38	0.35	0.31	37.0

3.2 Effect of Nitrogen Fertilizer and soil Type on Nitrogen Accumulation per Plant

Results on the effect of Nitrogen fertilizer rates and soil types on nitrogen accumulation per plant in 2010, 2011 and 2012 cropping seasons are presented in Table 2. Results showed that there was a significant effect ($P \leq 0.01$) in the three cropping seasons. In 2010 cropping season, nitrogen accumulation per plant was higher on sandy-loam soil (4.53%) than that**while 3.78% was recorded** on clay-loam soil (3.78%). In 2011 and 2012 cropping seasons, **higher** the nitrogen accumulation per plant **was also recorded** on sandy-loam soils was not significantly (P>0.05) different from that **with 4.32% while 4.01% was recorded** on clay-loam soils. **In 2012 cropping season, nitrogen accumulation in plants found on sandy-loam soil was 4.23% while 3.96 % was in plants on the clay-loam soil.** In all the three seasons, higher values were consistently obtained in plants on sandy-loam soil.

Effects of nitrogen fertilizer rates on nitrogen accumulation per plant in the three cropping seasons showed highly significant effects ($P \leq 0.01$). In 2010 cropping seasons, higher nitrogen accumulation per plant was recorded with the application of 80 kg N/ha which gave 4.60%, followed by 40 kg N/ha which gave 3.75%. The least value of 3.30% was obtained with 120 kg N/ha. In 2011 cropping season, the situation was different where the application of 160 and 120 kg N/ha produced plants with higher nitrogen accumulation with a value of 3.98% each. This was followed by 80 kg N/ha which gave 3.88%. Lower nitrogen contents were found on plants with 40 and 0 kg N/ha which had 3.83 and 3.05% respectively. In 2012 cropping season, the highest nitrogen accumulation per plant (4.01%) was found on plants that were applied 80 kg N/ha, followed by 40 kg N/ha, which gave nitrogen accumulation value of 3.98%. The application of 120 kg N/ha gave a value of 3.95%. A lower nitrogen

Formatted: Highlight

Comment [SSR7]: Seasonal difference in nitrogen accumulation is not shown in the results presented in Table 2. For example, in which season was nitrogen accumulation higher or lower than the other seasons? According to the results in Table 2, the data and thus the results for each season is completely independent of other seasons.

Formatted: Highlight

Comment [SSR8]: This is not a correct statement since in the 2011 and 2012 seasons, the nitrogen accumulation in sandy-loam soils was not significantly different from that of clay-loam soils. Look at the LSD values for 2011 and 2012.

Formatted: Highlight

content of plant was recorded with the application of 160 and 0 kg N/ha which gave a value of 3.66 and 3.63% respectively.

Table 2: Effect of Nitrogen Fertilizer Rates and Soil Type on Nitrogen Accumulation/plant for 2010, 2011 and 2012 Cropping Seasons (%)

	Nitrogen accumulation/plant		
Factors	**2010**	**2011**	**2012**
Soil type			
Clay-loam	3.78^{b}	4.01	3.96
Sandy-loam	4.53^{a}	4.32	4.23
Mean	4.15	4.16	4.10
Prob. of F	0.01	0.01	0.01
LSD$_{(0.05)}$	0.10	0.95(ns)	1.00(ns)
Fertilizer rates (Kg N/ha)			
0	3.43^{c}	3.05	3.63
40	3.75^{b}	3.83	3.98
80	4.60^{a}	3.88	4.01
120	3.30^{d}	3.98	3.95
160	3.53^{c}	3.98	3.66
Mean	3.72	3.74	3.84
Prob. of F	0.01	0.01	0.01
LSD$_{(0.05)}$	0.10	1.05(ns)	1.01(ns)

^{abc} = Means within the same column having different superscripts are significantly ($P \le 0.05$) different; LSD = Least significant difference; ns = non-significant

3.3 Effects of Nitrogen Fertilizer Rates and Soil Types on Nitrogen Uptake Efficiency

The effects of nitrogen fertilizer rates and soil types on nitrogen uptake efficiency in 2010, 2011 and 2012 cropping seasons are presented in Table 3. Results showed that there was a significant effect ($P \le 0.05$) between treatment means in 2010 and 2011 cropping seasons and highly significant effect ($P \le 0.01$) in 2012 cropping season.

In 2010 cropping season, the effects of soil types on nitrogen uptake efficiency revealed that higher nitrogen uptake efficiency was recorded on sandy-loam soil (2.19%) while the value of 1.78% was recorded on clay-loam soil. In 2011 cropping season, nitrogen uptake efficiency was higher in plants on the sandy-loam soil (1.89%) while clay-loam soil recorded 1.78%. In 2012 cropping season, a situation similar to that of 2010 cropping season was obtained where nitrogen uptake efficiency was higher in sandy-loam soil with a value of 2.01% while clay-loam soil produced 1.78%. Results showed that nitrogen uptake efficiency was consistently higher in plants on the sandy-loam soil in 2010, 2011 and 2012 cropping seasons.

Comment [SSR9]: No significant difference between all treatments in 2011 and 2012. So, this highlighted section needs to be corrected.

Formatted: Superscript

Formatted: Superscript

Formatted Table

Comment [SSR10]: With this LSD value, 4.32 is not significantly different from 4.01. In principle, as long as the difference between two mean values is less than the LSD, then the two mean values are not significantly different.

Formatted: Subscript

Formatted: Highlight

Formatted: Highlight

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Comment [SSR11]: According to LSD values given in Table 3. All treatment means for various seasons are non-significant. Carefully look at values presented in Table 3.

The effects of rates of nitrogen fertilizer on uptake efficiency showed that there was a highly significant effect ($P \leq 0.01$) in 2010, 2011 and 2012 cropping seasons. In 2010 cropping season, the highest nitrogen uptake efficiency was recorded with the application of 160 kg N/ha, followed by 40 kg N/ha which produced 2.19% and 1.78% respectively. The lowest nitrogen uptake efficiency of 1.51% was recorded with 0 kg N/ha application. In 2011 cropping season, the highest nitrogen uptake efficiency of 2.15% was recorded with 160 kg N/ha. However, the application of 120 and 40 kg N/ha produced plants with nitrogen uptake efficiency of 1.78% each. The least nitrogen uptake efficiency of 1.44% was recorded with 0 kg N/ha. In 2012 cropping season, nitrogen uptake efficiency was higher (2.01%) with the application of 160 kg N/ha, followed by 40 kg N/ha application with 1.85%. The least nitrogen uptake efficiency of 1.32% was recorded with 0 kg N/ha. The results showed that the application of 160 kg N/ha consistently produced the highest nitrogen uptake efficiency in 2010, 2011 and 2012 cropping seasons.

Table 3: Effect of Nitrogen Fertilizer Rates and Soil Types on Nitrogen Uptake Efficiency for 2010, 2011 and 2012 Cropping Seasons (%)

	Nitrogen uptake efficiency		
Factors	**2010**	**2011**	**2012**
Soil type			
Clay-loam	1.79	1.78	1.78
Sandy-loam	2.19	1.89	2.01
Mean	1.99	1.83	1.89
Prob. of F	0.03	0.03	0.01
$LSD_{(0.05)}$	1.11(ns)	1.01(ns)	1.01(ns)
Fertilizer rates (Kg N/ha)			
0	1.51	1.44	1.32
40	1.78	1.78	1.85
80	1.72	1.72	1.81
120	1.72	1.78	1.70
160	2.19	2.15	2.01
Mean	1.78	1.77	1.73
Prob. of F	0.01	0.01	0.01
$LSD_{(0.05)}$	1.11(ns)	1.13(ns)	1.01(ns)

[abc] = Means within the same column having different superscripts are significantly ($P \leq 0.05$) different; LSD = Least significant difference; ns = non-significant

Formatted: Highlight
Formatted: Highlight
Formatted: Highlight
Formatted: Highlight
Formatted: Highlight
Formatted: Highlight

3.4 Effects of Nitrogen Fertilizer Rates and Soil Types on Nitrogen Utilization Efficiency

The effects of nitrogen fertilizer rates and soil types on nitrogen utilization efficiency for the 2010, 2011 and 2012 cropping seasons are presented in Table 4. Results of the effect of soil types on nitrogen utilization efficiency showed that there was a highly significant effect (P≤0.01) in the three cropping seasons. In 2010 cropping season, nitrogen utilization efficiency was 39.7% on sandy-loam soil while 33.5% was recorded on clay-loam soil. Similar trend was maintained in 2011 and 2012 cropping seasons with slightly different values. However, results showed that sandy-loam soil produced plants with higher nitrogen utilization efficiency in 2010, 2011 and 2012 cropping seasons.

Results of the effects of nitrogen fertilizer rates on nitrogen utilization efficiency showed that there was a highly significant (P≤0.01) effect in the three cropping seasons. In 2010 cropping season, the application of 160, 120 and 80 kg N/ha demonstrated higher nitrogen utilization efficiency in plants with values of 39.6, 39.5 and 39.1% respectively. The application of 40 and 0 kg N/ha to plants resulted in lower nitrogen utilization efficiency where the value of 29.8 and 20.1% were recorded respectively.

In 2011 cropping season, the highest nitrogen utilization efficiency was recorded with 80 kg N/ha, which gave a value of 39.5%, which was followed by 160 kg N/ha with 39.1%. The plants with low nitrogen utilization efficiency (19.9%) were recorded with 0 kg N/ha. In 2012 cropping season, plants with the highest nitrogen utilization efficiency (39.9%) were recorded with 80 kg N/ha. The least value of 18.5% was recorded on plants treated with 0 kg N/ha.

Table 4: Effect of Nitrogen Fertilizer Rates and Soil Types on Nitrogen Utilization Efficiency for 2010, 2011 and 2012 Cropping Seasons (%)

	Nitrogen utilization efficiency		
Factors	**2010**	**2011**	**2012**
Soil type			
Clay-loam	33.5	38.9	37.2
Sandy-loam	39.7	39.1	39.3
Mean	36.6	39.0	38.2
Prob. of F	0.01	0.01	0.01
$LSD_{(0.05)}$	10.1(ns)	9.3(ns)	11.1(ns)
Fertilizer rates (Kg N/ha)			
0	20.1^{b}	19.9	18.5^{b}
40	29.8^{ab}	37.5	39.0^{a}
80	39.1^{a}	39.5	39.9^{a}
120	39.5^{a}	36.7	38.9^{a}
160	39.6^{a}	39.1	39.3^{a}
Mean	33.6	34.5	35.1
Prob. of F	0.01	0.01	0.01
$LSD_{(0.05)}$	11.1	10.3(ns)	10.3

^{abc} = Means within the same column having different superscripts are significantly (P≤0.05) different; LSD = Least significant difference; ns = non-significant

Comment [SSR12]: According to LSD values, no significant differences are observed between soil types.

Formatted: Highlight

Comment [SSR13]: Significant differences between treatment means exist in the results for 2010 and 2012. Mean values for 2011 are not significantly different at LSD value of 10.3.

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Highlight

3.5 Effects of Nitrogen Fertilizer Rates and Soil Types on Nitrogen Use Efficiency

The effects of rates of nitrogen fertilizer rates and soil types on nitrogen use efficiency in the 2010, 2011 and 2012 cropping seasons are presented in Table 5. Results of the effects of soil types on nitrogen use efficiency showed that there were highly significant effects (P≤0.01) in the three cropping seasons. In 2010 cropping season, nitrogen use efficiency was higher on sandy-loam soil with a value of 72.1% while it was 67.3% on clay-loam soil. A similar trend was maintained in 2011 cropping season where the nitrogen use efficiency on sandy-loam soil was 69.1% and clay-loam soil was 68.3%. In 2012 cropping season, nitrogen use efficiency on sandy-loam soil was 70.0% while on clay-loam soil was 68.0%. Results showed that nitrogen use efficiency was consistently higher on sandy-loam soil in all the three cropping seasons.

Results on the effects of nitrogen fertilizer rates on nitrogen use efficiency showed that there was a significant effect (P≤0.05) in 2010 cropping season and highly significant effect (P≤0.01) in 2011 and 2012 cropping seasons. In 2010 cropping season, the highest nitrogen use efficiency was recorded with 40 kg N/ha (72.1%) followed by 80 kg N/ha with 67.3%. The application of 120 and 160 kg N/ha produced nitrogen use efficiency of 59.1 and 57.0% respectively. In 2011 cropping season, the highest nitrogen use efficiency of 65.8% was recorded with only 40 kg N/ha, followed by 80 kg N/ha with 51.3% nitrogen use efficiency. With the application of 120 kg N/ha, the nitrogen use efficiency was 50.2%. In 2012 cropping season, the highest nitrogen use efficiency was recorded with 120 kg N/ha with a value of 72.1% which was followed by 80 kg N/ha with a value of 59.5%.

Table 5: Effect of Nitrogen Fertilizer Rates and Soil Type on Nitrogen Use Efficiency for 2010, 2011 and 2012 Cropping Seasons (%)

	Nitrogen use efficiency		
Factors	**2010**	**2011**	**2012**
Soil type			
Clay-loam	67.3	68.3	68.0
Sandy-loam	72.1	69.1	70.0
Mean	69.7	68.7	69.0
Prob. of F	0.01	0.01	0.01
$LSD_{(0.05)}$	15.7(ns)	18.1(ns)	15.7(ns)
Fertilizer rates (Kg N/ha)			
0	31.3^{b}	29.8^{c}	32.1^{c}
40	72.1^{a}	65.8^{a}	59.3^{ab}
80	67.3^{a}	51.3^{ab}	59.5^{ab}
120	59.1^{a}	50.2^{b}	72.1^{a}
160	57.0^{a}	49.5^{b}	53.3^{b}
Mean	57.3	49.3	52.2
Prob. of F	0.03	0.01	0.01
$LSD_{(0.05)}$	16.7	15.1	15.2

Formatted: Highlight

Comment [SSR14]: LSD values in Table 5 indicate otherwise.

Formatted: Highlight

Comment [SSR15]: In the 2010 cropping season, the nitrogen use efficiencies for all the treatments that received N fertilizer were similar, but were significantly higher than that of the control.

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Comment [SSR16]: But the two means are not significantly different

Formatted: Highlight

Comment [SSR17]: Not significantly different, including 59.3%

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

Formatted: Superscript

^{abc} = *Means within the same column having different superscripts are significantly (P≤0.05) different; LSD = Least significant difference; ns = non-significant*

4. DISCUSSION

The results of the current study showed that nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen use efficiency were affected by rates of nitrogen fertilizer and soil type. The results showed that nitrogen uptake efficiency was affected by rates of nitrogen fertilizer. This is in agreement with the report of Quaye *et al*. [11] of a significant interaction between applied nitrogen and soil water content of the maize plant. Generally, the total nitrogen in the plant (g N/plant) increased with an increase of nitrogen in the plant. Nitrogen application alone, however, cannot be attributed to nitrogen uptake ability of the maize plant. Other factors that influence the availability and uptake of nitrogen may be operating during the growth stages of the plant. Nitrogen uptake efficiency also depends upon the availability of nitrogen in the soil. Similar findings were reported by Rahimizadeh [12] that nitrogen uptake efficiency reflects the efficiency of the crop in obtaining nitrogen from the soil. Therefore, aboveground biomass increased as nitrogen level increased in the soil in line with the report of Worku *et al*. [6] that the above ground biomass increased with an increase in the rate of nitrogen fertilizer applied.

Furthermore, the results of the current study indicated that nitrogen use efficiency decreased with increasing nitrogen rate above 120 kg N/ha. Excess nitrogen applied may have lost to the environment through leaching and denitrification. When higher rates of nitrogen fertilizer were used in maize production, the nitrogen content not utilized by the crop is lost to the atmosphere through denitrification or goes beyond the root zone of crop through leaching. This agrees with the report of Sowers *et al*. [13] who reported that the application of high rates of nitrogen fertilizer would result in poor nitrogen uptake and low nitrogen use efficiency due to excess nitrogen losses. It is therefore imperative to apply nitrogen fertilizer when needed most by the crop plant. Use of optimum amount of nitrogen fertilizer through suitable application rates is imperative for higher nitrogen use efficiency. Nitrogen use efficiency can therefore be improved through matching application rate with crop demand as reported by Nemati and Sharifi [14]. Results on nitrogen use efficiency agree with the finding of Raun and Johnson [15] and Pierce and Rice [16] who reported that higher rates of nitrogen decrease nitrogen use efficiency in cereal. Lopez-Bellido and Lopez-Bellido [17] indicated that a decrease in nitrogen use efficiency with increasing fertilizer rates is because yield rises less than the nitrogen supply in the soil and fertilizer. Nemati *et al.* [14] also reported that nitrogen use efficiency decreased with increasing nitrogen rates but Kanampiu *et al.* [18] attributed the general decrease in nitrogen use efficiency with increasing nitrogen rates to increase in grain protein and nitrogen loss in the soil.

Loss of nitrogen from available pool, however, is dependent on the strength of competing nitrogen pathways including leaching, volatilization and immobilization from the time of application to uptake. Consequently, synchronization of nitrogen application with crop nitrogen demand may not lead to greater nitrogen use efficiency; rather it is the synchronization of nitrogen availability with plant nitrogen demand and uptake, coupled with the lack of synchronization of available nitrogen with competing nitrogen pathways that promotes greater nitrogen use efficiency.

5. CONCLUSION

The study revealed that the application of high nitrogen rates would result in poor nitrogen uptake and low nitrogen use efficiency due to excessive nitrogen losses. Therefore, the most logical approach to increasing nitrogen use efficiency is to supply nitrogen when it is needed by the crop. The study also revealed that nitrogen use efficiency is more optimal in sandy loam than clay loam soils. Based on the findings of this study, 120 kg N/ha (highest average nitrogen use efficiency achieved) is recommended for farmers in Yola.

REFERENCES

1. International Institute of Tropical Agriculture. Selected methods for soil and plant Analysis. IITA, Ibadan, Nigeria. 2009.

2. Sheldrick WF, Lingard J. The use of nutrient audits to determine Nutrient balance in Africa. Science Direct, Food policy. 2004; 29:61–98.

3. Tollenaar M, Dwyer LM. Physiology of maize. *In*: D.L. Smith and C. Hamel (ed.) Crop yield, physiology and processes. Springer Verlag, Berlin. 1999; 169‑204.

4. Onasanya RO, Aiyelari OP, Onasanya A, Oikeh S, Nwilene FE, Oyelakin O. Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizer in southern Nigeria. World Journal of Agricultural Science. 2009;5(4):400-407.

5. Sanchez PA. Linking climate change research with food security and poverty reduction in the tropics. Agriculture, Ecosystems and Environment. 2000;82:371-833.

6. Worku M, Banzigar M, Schulte G, Friesen D, Diallo AO, Horst WJ. Nitrogen uptake and utilization in contrasting nitrogen efficient tropical Maize hybrids. Crop Science Society of America, Madison, U.S.A. 2007.

7. United States Department of Agriculture. Food spending as a proportional Income. http://www.ers.usda.gov/publication/aer780/aer780f.pdf. 2009.

8. Kamara AY, Menkir A, Sanginga, N. Nitrogen use efficiency of maize genotype for tolerance to low Nitrogen and drought stress. International Institute of Tropical Agriculture, Ibadan Nigeria.. 2002.

9. Moll RH, Kamprath EJ, Jackson WA. Analysis and interpretation of factors which contribute to efficiency to nitrogen utilization. Agron. J. 1982; 74:562-564.

10. Statistical Analysis System Institute SAS / STAT software. Changes and enhancement through release 9.2. SAS institute, Cary NC. USA. 2009.

11. Quaye AK, Laryea KB, Abeney-Mickson S. Soil water and Nitrogen Interaction effect on maize (Z**z**ea mays L.) grown on vertisols. Journal of Forestry, Horticulture, and Soil Science. 2009; 3(1).

12. Rahimizadeh M. Kashani A. Zare-Feizabadi A. Koocheki AR. Nassiri-Mahallati M. Nitrogen use efficiency of wheat as affected by proceeding crop application rate of nitrogen and crop residues, Australian **Jounal**Journal of Crop Science. 2010; 3:89–93.

13. Sowers KE, Pan WL, Miller WC, Smith JL. Nitrogen use efficiency of split nitrogen application in soft white winter. Wheat. Agronomy Journal. 1994; 86:942–948.

Formatted: Font: Italic

14. Nemati AR, Sharifi RS. Effects of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn. International Journal of Agriculture and Crop Sciences. 2012.

15. Raun WR, Johnson GV. improving nitrogen use efficiency for cereal crop production Agronomy Journal. 1999; 91:357–363.

16. Pierce FJ, Rice CW. Crop rotation and its impact on efficiency of Water and nitrogen use, *In*: Hargrove (Eed). Cropping strategies for Efficient use of water and nitrogen. ASA, Special publication, No. 15 Wisconsin. 1988; 100–113.

17. Lopez-Bellido GRJ, Lopez-Bellido L. Effects of crop rotation and nitrogen fertilization on soil nitrate and wheat yield under rain-fed Mediterranean conditions. Agronomic. 2001; 21:509-516.

18. Kanampiu FK, Raun WR, Johnson GV. Effect of nitrogen rate on plant nitrogen loss in winter wheat varieties. J of Plant Nutr. 1997; 20:389-404.

Formatted: Font: Italic