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Growth and Yield Response of Maize (*Zea mays* L.) to Different Nitrogen Levels in Acid Soils

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The purpose of this study was to investigate the effects of different levels of nitrogen fertilizer on the growth and yield of maize (*Zea mays* L.) in Gondola district, Central Mozambique. The experiment was conducted during 2014/2015 and it was arranged in a randomized complete block design (RCBD) with four replications. The treatments consisted of three nitrogen levels (25.2 kg N ha^{-1}, 36 kg N ha^{-1}, 46.8 kg N ha^{-1}) and control. The results revealed that maize growth parameters (plant height, ear height, stem girth, and ear length) increased significantly (*p*<0.001) with increase in nitrogen level; and the level of 46.8 kg N ha^{-1} observed significantly the highest values. Maize yield characters, namely ear weight with pit, pitted ear weight, grain weight and 1000 grain weight, also increased significantly (*p*<0.001) with increase in nitrogen level. The nitrogen level of 46.8 kg N ha^{-1} observed significantly the highest values of these parameters. The N level of 46.8 kg N ha^{-1} observed significantly the highest maize grain yield (1.14 t ha-1; p<0.0001; CV=21.03%) than all other treatments. Pearson correlation coefficient analysis indicated that there were significant (*p*<0.05) positive relationships amongst maize growth characters, yield parameters and maize grain yield. The findings of the study concluded that nitrogen level of 46.8 kg N ha-1showed better performance of maize crop in terms of growth, yield, and yield attributes.

Keywords: Maize (*Zea mays* L.), Nitrogen levels, Grain Yields, Acid soils.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop which is grown widely in many countries of the Southern Africa region (FAO, 2013). For instance, in Mozambique maize is the number two food staple crop, being cultivated on area of 1608 thousand hectares giving annual production of 1207 thousand tonnes with average yield of 750.6 kg ha^{-1} (Mozambican Statistical Yearbook, 2013). According to the same source, the area planted of maize increased from 1.43 million hectares in 2010 to 1.61 million hectares in 2013. This expansion of the land area devoted to maize crop resulted in increased production by about 11.2%.

In spite of the increase in land area under maize production, grain yield is still low, about 1.0 t ha^{-1} against an average of 2.0 t ha^{-1} from the main maize producers in Africa (FAO, 2013). This could be related to the fact that it is mainly being practiced under subsistence conditions by smallholder farmers (FAO, 2013). The majority of these farmers cannot afford to purchase sufficient amount of mineral fertilizers to replace soil nutrients removed through harvested crop products (Jama *et al*., 2000), crop residues, and through loss by runoff, leaching and as gases (Bekunda *et al*., 1997). Consequently, poor soil fertility has emerged as one of the greatest biophysical constraint to increasing agricultural productivity.

Smaling *at al*. (1993) stated that Nitrogen, Phosphorus and Potassium are often the most limiting macronutrients in many soils, in the order N>P>K. The maize crop requires adequate supply of nutrients particularly NPK for good growth and high yields. Nitrogen and phosphorus are very essential for good vegetative growth and grain development in maize production. The quantity required of these nutrients particularly nitrogen depends on the pre-cleaning vegetation, organic matter content, tillage methods and light intensity (Kang, 1981). Nitrogen is a vital plant nutrient and a major yield determining factor required for maize production (Shanti *et al*., 1997; Adediram and Banjoko, 1995).

Nitrogen can alter plant composition much more than any other mineral nutrient as it is an indispensable elementary constituent of many organic metabolites including nucleic amino acids, proteins, nucleic acids, and phytochromes (Anonymous, 2000). Thereby, N is the motor of plant growth and makes up 1 to 4% of dry matter of the plants (Taiz and Zeiger, 2010). It also mediates the utilization of P, K, and other elements in plants (Onasanya *et al*., 2009). It is widely accepted that crops grown on soils deficient in N, exhibit very distinctive N-deficiency symptoms such as poor growth, chlorosis, necrosis and causes disorder in many physiological/biochemical characteristics of plants (Taiz and Zeiger, 2010). The use of N-fertilizers along with other nutrients has been suggested to enhance the crop productivity (Marschner, 1995). According to Raun and Johnson (1999) an estimate of 33% N-fertilizers are being used worldwide for improving cereal production.

The response of maize plant to application of N-fertilizers varies from variety to variety, location to location and also depends on the availability of the nutrients (Onasanya *et al*., 2009). Various studies have shown that maize varieties differ in grain yield response to nitrogen fertilization (Bundy and Carter, 1988). Previous findings indicated that the increase in maize grain yield after nitrogen fertilization is largely due to an increase in the number of ears per plant, increase in total dry matter distributed to the grain and increase in average ear weighing (Nxumalo *et al*., 1993). El-Sheikh (1998) reported that application of 160 kg N ha^{-1} significantly increased grain yield of maize. On the contrary, nitrogen deficiency decreased grain yield.

Additionally, Badr and Authman (2006) found that increasing level of nitrogen fertilizer led to increase in grain yield and its components. Increasing nitrogen fertilizer rate from zero up to 250 kg N ha^{-1} increased, significantly, the maize growth, yield and yield components characters (Bakht *et al*., 2006). Khan *et al.* (2012) showed that increase of N levels enhanced final seed yield due to increase of seed number in each ear, also, N levels had, significantly, affected the maize plant height. Increasing of both qualitative and quantitative yield and some agronomic characteristics such as plant height, cob length and diameter should be applied 225 Kg N ha^{-1} (Nemati and Sharifi, 2012). Also, Sharifai *et al.* (2012) indicated that the effect of nitrogen on yield components was significant as the response was in the range of 80 to 120 kg ha^{-1}. Likewise, Moraditochaee *et al.* (2012) showed that the effect of nitrogen fertilizer on grain yield, straw yield, harvest index, plant height, number of ear per plant, 1000 grain weight and ear length were significant. Keeping in view the above facts, the present study was conducted to investigate effects of different levels nitrogen fertilizer on the growth and yield of maize (Zea mays L.) in Gondola district, Central Mozambique.

MATERIALS AND METHODS

Study area

The field trials were carried out in Gondola District (Figure 1), Manica province of Central Mozambique, which occupies an area of 5290 km^2 and population of 310429 habitants with population density of about 53.8 habitants per km^2. Table 1 shows the soil characteristics of the experimental site. The experiment lies between Latitude 17^o N and Longitude 36^o E, and at the altitude of 593m above the sea level.

The region is covered by humid temperate climate strongly influenced by altitude. It shows a wide variation of rainfall, 850 mm to 1500 mm, with most of the rainfall (about 90%) going from late November to early March. Rainfall for the 2014/2015 growing season in which the experiment was carried out is presented in Figure 2. The standard temperature is conditioned by altitude, which ranges from 700 m to 1600 m, with an average temperature of 22.3°C. The topography is dominantly very undulating to dissected (Government of Mozambique, 2005).

Experimental design and management

Before planting, soil samples from the experimental sites were collected at 0 to 15 cm depth for analysis of organic carbon, total nitrogen using standard methods, extractable P, Ca, Mg, K, Na using Mehlich-1 (M1) extraction method, where P and Mg^{2+} were determined colourimetrically in a spectrophotometer and Ca^{2+}, and K^+ were determined using flame photometer. The concentrations of copper, manganese, iron, boron, and zinc in soil were determined by flame atomic absorption spectrometry (Okalebo *et al.,* 2002). The field was ploughed using hand hoe and left as such for one week. The planting was done on the 18th of December 2014. The test crop was maize (*Zea mays* L.) var. ZM523, which was planted at a spacing of 0.75 m 0.50 m inter

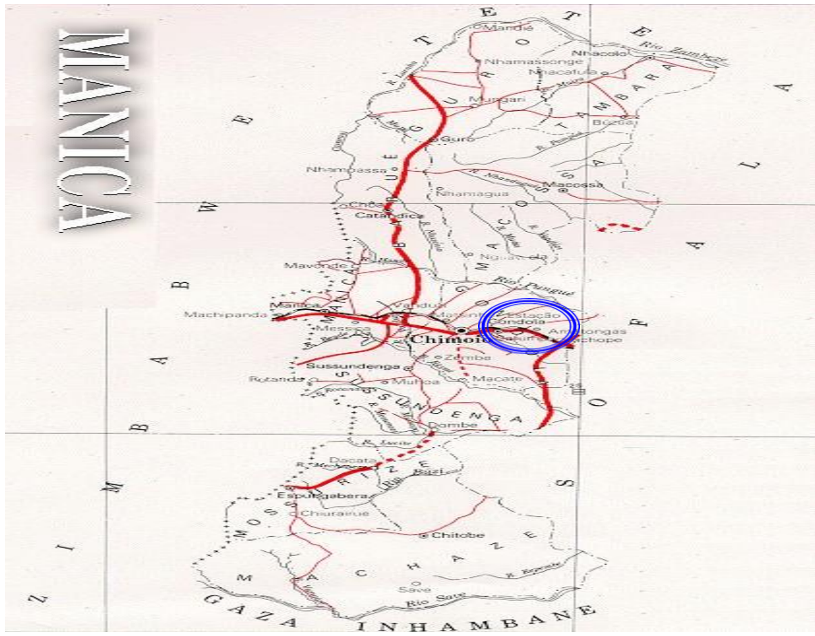

Figure 1: Map of the experimental sites.

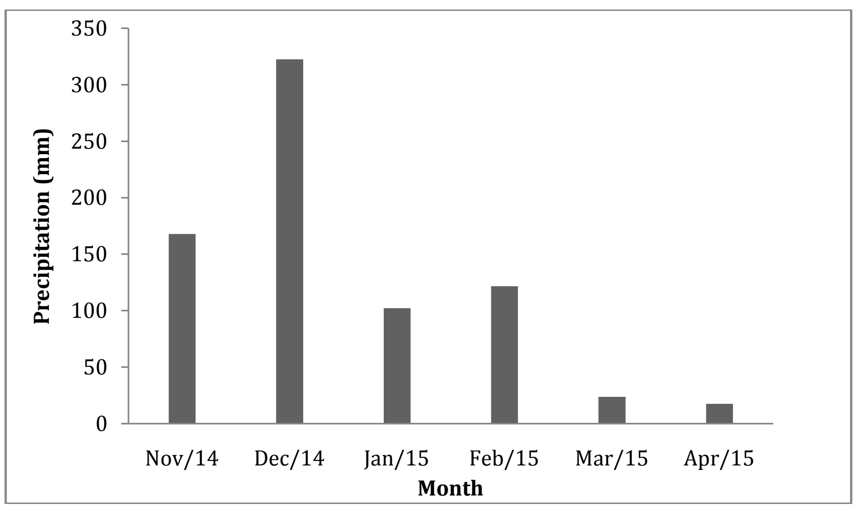

Figure 2: Precipitation (mm) of the study site

and intra-row, respectively. The number of hills per row was 10 with three seeds per hill in order to ensure maximum plant population and to account for germination failure; and two weeks after germination the excess plants were thinned out to remain with two plants per hill. The experiment was established in the Administrative Post of Amatongas (Gondola district) and it was laid out as a randomized complete block design (RCBD) with four replicate blocks and plot sizes measuring 7 m × 4.5 m. Pathways measuring 2.0 m and 1.0 m were left between the blocks and plots, respectively. The treatments were control, 25.2kg N ha^{-1}, 36 kg N ha^{-1}, and 46.8 kg N ha^{-1} (Table 2). The sources of N were NPK 12-24-12 (basal application) and Calcium Ammonium Nitrate – CAN 27% (as top dressing). It was also done blank application of 30 kg P_2O_5 ha^{-1} and 14.4 kg K_2O ha^{-1}, at planting.

Data collection

Maize grain and stover was harvested at maturity from a net area of each treatment demarcated after leaving out

Table 1: Soil characteristics at experimental sites

Soil parameter	Value
pH in water (1:2.5)	5.81
pH in KCl	4.71
Available N (mg kg^{-1})	16.44
Available P (mg kg^{-1})	8.80
Available S (mg kg^{-1})	19.50
Exchangeable K^+ (mg kg^{-1})	125.20
Exchangeable Ca^{2+} (mg kg^{-1})	347.60
Exchangeable Mg^{2+} (mg kg^{-1})	84.10
Exchangeable Na^+ (mg kg^{-1})	8.10
Cupper Cu (mg kg^{-1})	0.80
Zinc Zn (mg kg^{-1})	0.50
Manganese Mn (mg kg^{-1})	6.90
Iron Fe (mg kg^{-1})	4.70
Boron B (mg kg^{-1})	0,10
Soil Organic Carbon (%)	1,50
Organic Matter (%)	2,70
Soil Density (g/cm^3)	1,10

Table 2: Treatment description

Treatment		Abbreviations	Description of treatments
1.	Control	N0	No fertilizer
2.	25.2kg N ha^{-1}	N1	120 kg NPK 12:24:12 ha^{-1} plus 40 kg CAN (27%) ha^{-1}
3.	36 kg N ha^{-1}	N2	120 kg NPK 12:24:12 ha^{-1} plus 80 kg CAN (27%) ha^{-1}
4.	46.8 kg N ha^{-1}	N3	120 kg NPK 12:24:12 ha^{-1} plus 120 kg CAN (27%) ha^{-1}

two rows on each side of the plot and the first two and the last two plants on each row to minimize the edge effect. The entire plants on the plots was harvested by cutting at the ground level and weighted to represent the total fresh weight. Maize cobs were manually separated from the stover, sun-dried, and packed in sacks before threshing. After threshing, moisture content of the grains was determined using a moisture meter and grain yield adjusted to 12% moisture content using the following formula. Similarly, yield was calculated using the following formulas:

$$Adjusted\ yield = measured\ yield * \frac{(100 - sample\ moisture\ content)}{(100 - standard\ moisture\ content)} \quad (1)$$

$$Yield\ (t/ha) = 10 * \frac{Dry\ weight\ (kg/m^2)}{Net\ area\ (m^2)} \quad (2)$$

It was also collected data on plant height, ear height, stem girth, ear length, and ear weight per plant. These parameters were taken as follows: Plant height: This was taken from a sample of ten randomly selected maize plants marked within each plot. A carpenter's tape was used for measuring the height from the ground level to the top-most leaf. The mean from the ten plants was then determined. Ear height: This was taken from a sample of ten randomly selected maize plants marked within each plot. A carpenter's tape was used for measuring the height from the ground level to the ear insertion node. Stem girth: This was also taken from a sample of ten cobs per plot with the use of tailor's tape and the values were recorded and averaged. Ear length: The length of ten dehusked maize ear per plot was measured with a tape and the mean value calculated. Ear weight per plot: The weight of the all ears per plot was weighed.

Data analysis

Data of maize yields and growth parameters were

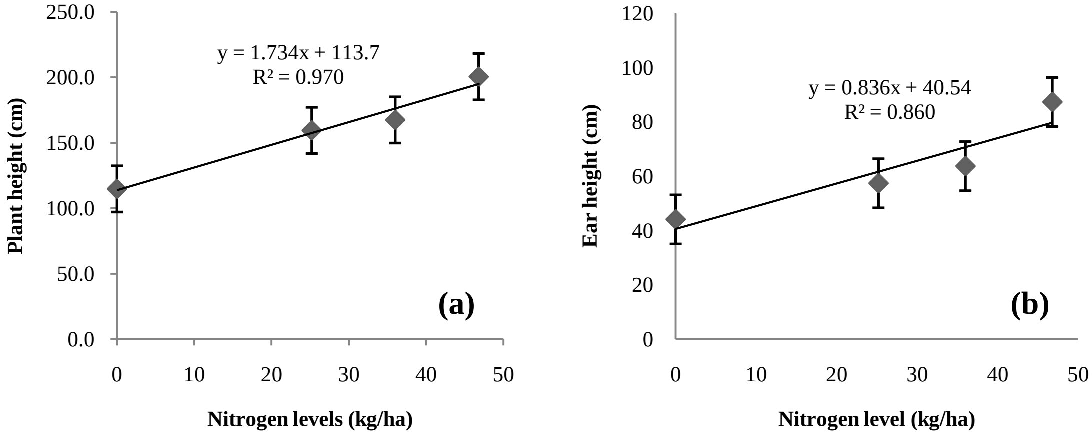

Figure 3: Plant height (a) and ear height (b) of maize plants exposed to 0, 25.2, 36 and 46.8 kg N ha^{-1}. (Bars represent standard errors of means).

subjected to Analysis of Variance (ANOVA) using SAS version 9.0 to test for significant differences between different treatments, the yields were subjected to *t-student* test at 95% of significance level (p < 0.05).

RESULTS AND DISCUSSION

Maize growth parameters

There were significant differences (p<0.05) between the treatments due to treatment effect. The data recorded in Table 3 showed that plant height increased across the treatments at all. The control treatment observed significantly the lowest plant height than all other treatments with 146.3 cm (p=0.0444); the level of 46.8 kg N ha^{-1} observed statistically the highest plant height (200.5 cm; p=0.0444; CV=21.8%) then the control treatment; but it was at par with the 25.2 kg N ha^{-1} and 36 kg N ha^{-1} treatments (Table 3). This could be attributed to a mere fact that higher rates of nitrogen may have caused rapid cell division and elongation. Similarly, in Tanzania Adamu *et al.* (2015) reported significant differences in maize plant height after varying N levels; the control treatment observed the lowest plant height while the highest level of nitrogen also observed the highest plant height. In Nigeria, Onasanya *et al.* (2009) found that the plant height was significantly influenced by the treatments, and the control treatment was reported to observe the lowest plant height. Other researches (Amanullah *et al*., 2014; Kandil, 2013; Khan *et al*., 2012; Namati and Sharifi, 2012; Hammad *et al*., 2011; Asgha *et al.,* 2010) also reported that plant height differed significantly (p<0.05) among the treatments.

The ear height differed significantly (p<0.0001) among the treatments. For instance, the treatment of 46.8 kg N ha^{-1} observed significantly highest ear height (87.3 cm; p=0.0001; CV=7.2%) than all other treatments (Table 3). Similarly, in Brazil Okumura *et al.* (2011) reported that the ear height differed significantly among the treatments. Also, Santos *et al.* (2002) reported that there is a positive correlation between nitrogen levels and ear height.

In plant height, the linear regression coefficient was 0.97 (Figure 3a). In relation to ear height the linear regression coefficient was 0.86 (Figure 3b). In this study the increase in nitrogen level influenced positively the plant height and ear height of maize plants. These findings were also reported by Okumura *et al.* (2011) and Santos *et al*. (2002).

The ear length and the stem girth were significantly affected by the treatments (p=0.0001). For instance, the level of 46.8 kg N ha^{-1} observed statistically the highest ear length (23.9 cm; p<0.0001; CV=3.1%) and stem girth (9.7 cm; p=0.0001; CV=6.9%) than all other treatments (Table 3). Similarly, Adamu *et al*. (2015) reported that Stem girth differed significantly (p = 0.05) among the treatments. These findings were also reported by other researchers (Amanullah *et al*., 2014; Kandil, 2013; Okumura *et al.,* 2011; and Santos *et al.,* 2002).

In stem girth, the linear regression coefficient was 0.95 (Figure 4a). In relation to ear length the linear regression coefficient was 0.92 (Figure 4b). In this study the increase in nitrogen level influenced positively the stem girth and ear length of maize plants. These findings were also reported by Okumura *et al.* (2011) and Santos *et al*. (2002). Characters linked to ear were positively influenced by nitrogen fertilization, and this fact is secondary, because N has influence on division and expansion of cell and photosynthetic process (Okumura *et al*., 2011) with consequent better root and shoots development. Contrasting results were reported by Cruz *et al*. (2008) and Fernandes *et al*. (2005), that ear length

Table 3: Effects of different N fertilizers on maize growth parameters

Traetment	Plant height (cm)	Ear height (cm)	Ear length (cm)	Stem girth (cm)
Control	146.3c	44.1c	15.1d	6.3c
25.2kg N ha^{-1}	159.5ab	57.4b	17.5c	7.7b
36 kg N ha^{-1}	167.5ab	63.7b	20.7b	8.3b
46.8 kg N ha^{-1}	200.5a	87.3a	23.9a	9.7a
p-value	0.0444*	0.0001***	<0.0001***	0.0001***
LSD $_{(0.05)}$	56.1	7.92	0.94	0.89
CV (%)	21.8	7.2	3.1	6.9

* Significant at $p \leq 0.05$; ***significant at $p \leq 0.0001$;

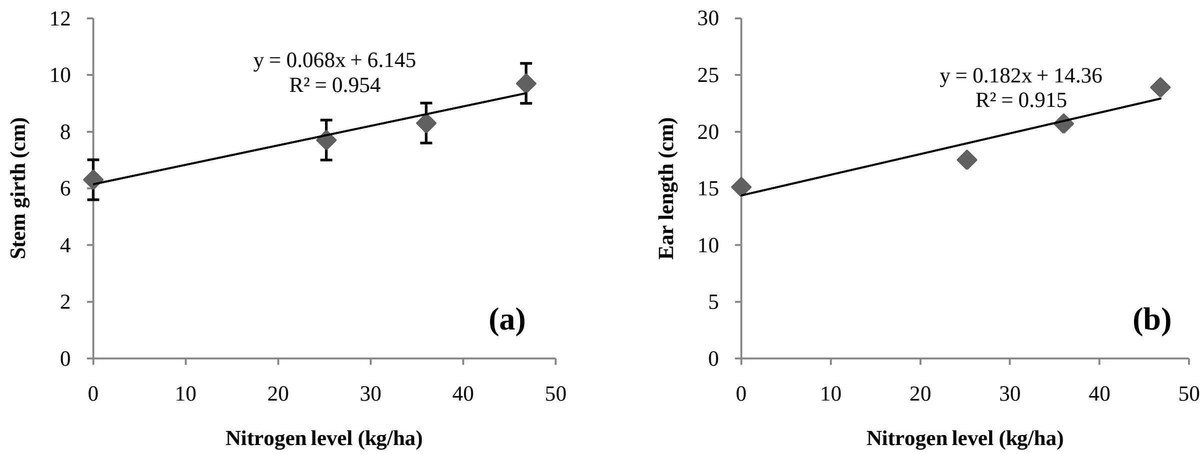

Figure 4: Stem girth (a) and ear length (b) of maize plants exposed to 0, 25.2, 36 and 46.8 kg N ha^{-1}. (Bars represent standard errors of means).

Table 4: Effects of different N fertilizers on maize yield parameters and yield

Traetment	Ear weight with pit (kg)	Pitted ear weight (kg)	Grain weight (kg)	1000 grain weight (g)	Grain yield (t ha^{-1})
Control	5.3d	3.3c	1.8b	127.9c	0.25c
25.2kg N ha^{-1}	8.8c	4.9c	3.0b	145.5c	0.42c
36 kg N ha^{-1}	12.3b	10.4b	5.6a	192.3b	0.78b
46.8 kg N ha^{-1}	16.5a	14.3a	6.5a	236.8a	1.14a
p-value	<0.0001***	<0.0001***	0.0010**	0.0012**	<0.0001***
LSD $_{(0.05)}$	2.53	2.88	1.88	43.24	0.22
CV (%)	14.75	21.87	27.83	15.39	21.03

** Significant at $p \leq 0.001$; ***significant at $p \leq 0.0001$.

is not influenced by nitrogen level. Ferreira *et al.* (2001) investigating effect of four nitrogen levels over agronomical characteristics of maize plants, found that ear length was positively influenced by increase in nitrogen rate.

Maize yield parameters and grain yield

Maize yield depends on yield components. The data (Table 4) revealed that both maize grain yield and yield contributing characters (ear weight with pit, pitted ear weight, grain weight and 1000 grain weight) were significantly (p<0.0010) affected by the nitrogen levels.

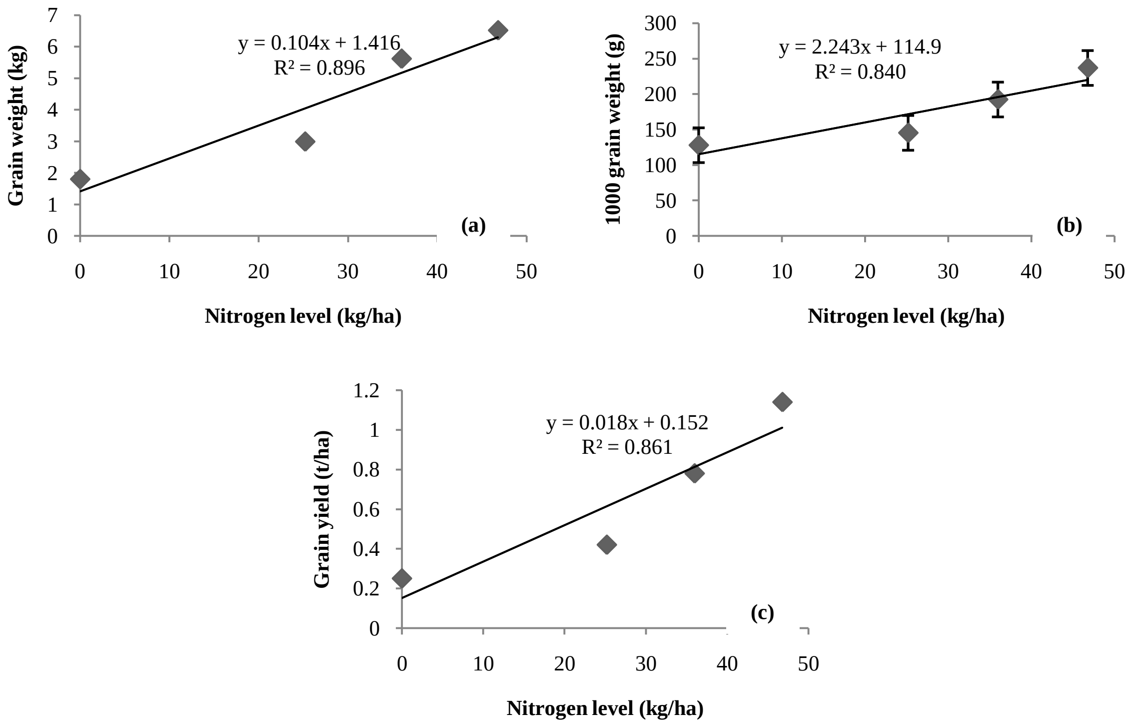

Figure 5: Grain weight (a), 1000 grain weight (b), and grain yield (c) of maize plants exposed to 0, 25.2, 36 and 46.8 kg N ha^{-1}. (Bars represent standard errors of means).

For instance, maximum value of pitted ear weight and with pit were produced by level of 46.8 kg N ha^{-1}, with 16.5 kg (p<0.0001; CV=14.75%) and 14.3 kg (p<0.0001; CV=27.83%), respectively; while minimum values (5.3kg and 3.3 kg, respectively) were obtained from control treatment. Similarly, nitrogen level of 46.8 kg N ha^{-1} recorded maximum values of grain weight (6.5 kg; p=0.001; CV=27.83%), 1000 grain weight (236.8 g; p=0.0012; CV=15.39%) and grain yield (1.14 t ha^{-1}; p<0.0001; CV=21.03%). As reported by Amanullah *et al*. (2014) that individual grain weight or 1000 grain weight are regarded as the basis for final economic yield, higher nitrogen rate can promote leaf area development during vegetative development and maintaining functional leaf area during growth period may be the possible reason for photo assimilate formation and increase in grains weight. The findings of this study are in line with other researchers (Gul *et al*., 2015; Amanullah *et al*., 2014; Kandil, 2013; Khan *et al*., 2012; Namati and Sharifi, 2012; Hammad *et al*., 2011; Okumura *et al.* (2011); Asgha *et al.,* 2010) who reported that maize yield contributing parameters and maize grain yield differed significantly (p<0.05) among the treatments.

Grain weight (Figure 5a), 1000 grain weight (Figure 5b), and maize grain yield (Figure 5c) presented linear behaviour in rates of nitrogen evaluated with regression coefficients of 0.90, 0.84, and 0.86, respectively. Increase in grain weight and yield was promoted by adequate nitrogen supply, because nitrogen absorbed by plants is responsible by fixation of carbon skeletons to amino acids synthesis (Marschner *at el*., 1995), which results in several proteins that have specific functions in plant metabolism. In addition, during grain filling period these carbon compounds previously fixed are broken down, transported and stored in form of proteins and amino acids (Okumura *et al*., 2011). Gul *et al*. (2015) reported that maize grain yield was linearly influenced by nitrogen levels applied. Bashir *et al.* (2012), Okumura *et al*. (2011), Deparis *et al*. (2007), Cruz *et al*. (2008) and Bastos *et al*. (2008) showed also linear behaviour linked to yield in maize induced by increase in nitrogen level.

Relationship between growth and yield parameters

Correlation analysis indicated that there were significant (p<0.05) positive relationships amongst maize growth characters, yield parameters and maize grain yield. For instance, ear length and grain yield were significantly (r=0.95***), ear weight with pit and grain yield (r=0.95***), 1000 grain weight and grain yield (r=0.86***). The findings of this study were also reported by other researchers (Okumura *et al.,* 2011; Cruz *et al*., 2008; and Gomes *et al*., 2007).

Table 5: Correlation coefficients among maize agronomic characteristics

Parameter	Ear height	Stem girth	Ear length	Ear weight with pit	Pitted ear weight	Grain weight	1000 grain weight	Grain yield
Plant height	0.77***	0.71**	0.68**	0.63**	0.60**	0.51*	0.64**	0.60**
Ear height		0.79**	0.91***	0.85***	0.83***	0.69**	0.76***	0.84***
Stem girth			0.90***	0.88***	0.87***	0.79***	0.88***	0.88***
Ear length				0.94***	0.95***	0.84***	0.87***	0.95***
Ear weight with pit					0.96***	0.91***	0.83***	0.95***
Pitted ear weight						0.90***	0.85***	0.98***
Grain weight							0.80***	0.91***
1000 grain weight								0.86***

*Significant at $p \leq 0.05$; significant at $p \leq 0.001$; **** significant at $p \leq 0.0001$.

CONCLUSIONS

According to the findings of this study it can be concluded that,

> Maize growth parameters (plant height, ear height, stem girth, and ear length) increased significantly with increase in nitrogen level. Maize yield characters, namely ear weight with pit, pitted ear weight, grain weight and 1000 grain weight increased significantly with increase in nitrogen level. Maize grain yield was increased by nitrogen rates evaluated. It was possible to visualize relationships amongst maize growth characters, yield parameters and maize grain yield.

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