Effect of nitrogen fertilization and cultivar on growth and grain yield of maize (*Zea mays* L.), Gezira State, Sudan

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ABSTRACT

Maize (*Zea mays* L.) is the world's third leading cereal crop after wheat and rice. In the last two decades, maize gained more importance as a forage and food crop in the Sudan. The objective of this study was to determine the optimum level of nitrogen that maximizes grain yield of maize. This study was conducted at the Experimental Farm, University of Gezira, during the summer and winter seasons of 2016/2017. Eight treatments, namely, four nitrogen levels (0, 43, 86 and 129 kg N/ha) and two cultivars, namely, Hudeiba 1 and Hudeiba 2 were used. A randomized complete block design (RCBD) with three replicates was used. Results indicated that nitrogen had a significant ($P \leq 0.05$) effect on leaf area index, number of days to 80% silking and number of rows/ear in the winter season only, and number of grains/ear in the summer season only. Cultivars had significant effects ($P \leq 0.05$) on number of grains/ear and number of days to 80% silking in the summer and winter seasons, respectively. The results also showed that nitrogen had a significant ($P \leq 0.05$) effect on grain yield in both seasons. The highest grain yield (2.4 and 2.1 t/ha) was obtained when 86 kg N/ha was applied to Hudeiba1 and Hudeiba 2 in summer and winter seasons, respectively. To maximize grain yield of maize, it could be recommended that 86 kg N/ha should be applied to Hudeiba1 and Hudeiba 2 in both seasons.

INTRODUCTION

Maize (*Zea mays* L.) is an annual cross pollinated summer crop. It belongs to the family Poaceae. Maize is a typical monoecious plant highly cross-pollinated (95%), yet self-pollination may reach up to 5% (Poehlman and Sleper, 1995). Maize was originated in America and first cultivated in the area of Mexico more than 7000 years ago, and spread throughout South America (Hailare, 2000).

Maize is used in agro-industries for manufacturing corn oil, corn flakes and corn sugar (Harris *et al.*, 2007). In the world production, maize ranked third among cereal crops after wheat and rice (Zamir *et al.*, 2013). It is produced mainly in temperate countries as well as some tropical zones. In 2014, the United States topped the list of ten maize producing countries which includes China, Brazil, EU, Ukraine, Argentina, India, Mexico, South Africa and Canada with an amount of about 351 million metric tons (Statista, 2015). World production of white maize is currently estimated to be around 65 to 70 million tons. Among the individual geographical regions of the developing countries, white maize production has a paramount importance in Africa. The main maize producing countries in Africa are Kenya, Tanzania, Zambia and Zimbabwe (Kidist, 2013).

Maize is adapted to different soil types and conditions. It grows best on deep, fine structured, well aerated and drained soil that is rich in organic matter and has a high field capacity. However, with good cultural practices and fertilizer application, maize can give good yields on almost any type of soil with a pH range of 5 to 7 (Romain, 2001). Grain yield of maize in Africa is very low (1.2 to 2.5 t/ha) compared to 6.2 t/ha in developed countries. This was attributed to low plant density and low levels of inputs used especially fertilizers (Romain, 2001).

In the Sudan, maize is grown on a small scale under rain, flood and irrigated conditions. Maize, like many cereal crops, requires certain quantities of some elements such as nitrogen, phosphorus and potassium for maintaining good yields. High yields of maize have been obtained in the tropics mainly through the use of improved genotypes, fertilizer application and good cultural practices (Sallah *et al*., 1998). Therefore, the objective of this study was to examine the effects of different levels of nitrogen on growth and grain yield of maize in central Sudan.

MATERIALS AND METHODS

Field experiments were conducted for two consecutive seasons, summer and winter (2016/17), at the Experimental Farm of the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan, latitude 14° 06´N and longitude 33° 38´E and altitude 407 masl. The area is characterized by hot semi-arid climate. The soil of the experimental site is typical Sulemi soil series, dark brown, deep cracking clays with very low permeability when moist, pH ranges from 7.9 to 8.4, nitrogen 0.03% and available phosphorus from 4.3 to 6.9 mg/kg soil. The soil is non-saline and non-sodic (Soil Survey Staff, 1999). Treatments consisted of two maize cultivars (Hudeiba1, Hudeiba 2) and 4 levels of nitrogen (0, 43, 86 and 129 kg/ha) in the form of urea. A randomized complete block design with three replicates was used. The plot size was 4X3.5 m (14 m^2). Seeds of maize cultivars were brought from the Agricultural Research Corporation.

The experimental site was disc plowed, harrowed, leveled and ridged 80 cm apart. Seeds of Hudeiba 1 and Hudeiba 2 were sown in holes 30 cm apart on the 13th of July 2016 (summer sowing) and the 24th of November 2016 (winter sowing). Two to three weeks after sowing, plants were thinned to one plant per hole. Irrigation was applied immediately after sowing to ensure adequate crop establishment. Subsequent irrigations were given every 7 – 10 days. Weeds were removed twice manually, three and six weeks after sowing. The traits measured were leaf area index (LAI), days to 80% silking, number of rows/ear, number of kernels/ear and grain yield (t/ha). Data were analyzed using the standard analysis of variance procedure. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Leaf area index (LAI)

Effect of nitrogen levels, maize cultivar and their interaction on leaf area index (LAI) in summer and winter seasons is shown in Table 1. Nitrogen levels had a significant ($P \leq 0.05$) effect on leaf area index in winter season only. The highest leaf area index (3.3) was obtained when 86 kg N/ha were applied in both seasons. Cultivars had no significant effect on leaf area index in both seasons. The interaction of nitrogen levels and cultivars on leaf area index was significant in the winter season only. The highest leaf area index (4.0) was obtained by Hudeiba 2 when 86 kg N/ha were applied. The lowest leaf area index (2.1) was obtained by Hudeiba 2 when 0 kg N/ha was applied. These findings are in line with those of Workayehu (2000) who reported that application of nitrogen fertilizer increased leaf area index in maize which increased photosynthetic activity.

Table 1. Effect of nitrogen levels on leaf area index (LAI) of two maize cultivars during the summer and winter seasons (2016/ 17).

Nitrogen level (kg/ha)	Hudeiba1	Hudeiba2	Mean
	Summer season		
0	2.8	3.1	3.0
43	2.8	2.9	2.9
86	3.2	3.4	3.3
129	2.5	3.9	3.2
Mean	2.8	3.3	3.1
Sig. level	NS	NS	NS
SE± (interaction)	0.7		
CV%	23.4		
		Winter season	
0	2.9	2.1	2.5
43	3.0	3.3	3.2
86	2.5	4.0	3.3
129	2.2	2.4	2.3
Mean	2.7	2.9	2.8
SE± (interaction)	0.5		
CV%	18.8		

Days to 80% silking

Nitrogen levels, cultivar and their interaction had significant effects on days to 80% silking in winter season only (Table 2). The highest number of days (68 days) was recorded by Hudeiba 2 when 86 and 129 kg N/ha were applied in the winter season only. The cultivar had significant ($P \leq 0.05$) effect on number of days to 80% silking. The highest number of days to 80% silking (67) was obtained by Hudeiba 2 in the winter season only. The interaction effect of nitrogen levels and cultivars on days to 80% silking was highly significant ($P \leq 0.01$) in winter season only. The highest number of days to 80% silking (68 days) was recorded by Hudeiba2 when 86 and 129 kg N/ha were applied. These results disagree with those of Mohamed *et al*. (2008) who found that nitrogen rate had no significant effect on number of days to 50% silking. They explained that, this parameter was governed by genetic factors.

Table 2. Effect of nitrogen levels on number of days to 80% silking of two maize cultivars grown during the summer and winter seasons (2016/ 17).

Nitrogen level (kg/ha)	Hudeiba1	Hudeiba2	Mean
	Summer season		
0	63.0	61.0	62
43	59.3	61.0	60
86	60.7	59.3	60
129	60.7	59.3	60
Mean	60.9	60.1	60.5
Sig. level	NS	NS	NS
SE± (interaction)	2.3		
CV%	3.8		
	Winter season		
0	64.0	64.7	64.3
43	66.7	67.0	66.8
86	60.3	68.0	64.1
129	63.3	68.0	65.6
Mean	63.5	67	65.2
SE± (interaction)	1.3		
CV%	20		

Number of rows/ear

Nitrogen levels had significant effect on number of rows /ear in the winter season only (Table 3). The highest number of rows/ear (14 each) was obtained when 86 and 0 kg N/ha were applied in summer and winter seasons, respectively. Cultivars had no significant effect on number of rows/ear in both seasons. The interaction effect of nitrogen levels and cultivars had a significant ($P \leq 0.05$) effect on number of rows /ear in the winter season only. However, the highest number of rows (14) was obtained when 43 kg N/ha and 0 kg N/ha were applied to Hudeiba1 and Hudeiba 2 in both seasons. These results disagree with those of Arif *et al*. (2010) who found no significant effects on number of rows/ear when 80, 120 and 160 kg N/ ha were applied.

Table 3. Effect of nitrogen levels on number of rows/ear of two maize cultivars during the summer and winter seasons (2016/ 17).

Nitrogen level (kg/ha)	Hudeiba1	Hudeiba2	Mean
	Summer season		
0	13.7	12.3	13.0
43	14.5	12.6	13.5
86	13.7	14.1	13.9
129	13.7	13.7	13.4
Mean	13.7	13.2	13.4
Sig. level	NS	NS	NS
SE± (interaction)	0.8		
CV%	5.9		
	Winter season		
0	14.2	14.7	14.4
43	13.7	13.6	13.6
86	12.65	13.3	12.9
129	13.8	12.3	13
Mean	13.6	13.5	13
SE± (interaction)	0.6		
CV%	4.4		

Number of kernels/ear

Nitrogen levels, cultivars and their interaction had significant effects ($P \leq 0.05$) on number of kernel/ear in the summer season only (Figs 1 and 2). The highest number of kernel/ear (442 and 383) was obtained when 129 kg N/ha and 86 kg N/ha were applied during the summer and winter seasons, respectively. Hudeiba1 and Hudeiba 2 obtained the highest number of kernels/ear (432.9, 400 and 381,364) in the summer and winter seasons, respectively (Fig. 2). The interaction between nitrogen levels and maize cultivars had a significant effect on number of kernel/ear in the summer season. The highest number of kernels/ear (466.5 and 407) was obtained by Hudeiba1 and Hudeiba 2 when 0kg N/ha was practiced in the summer and winter seasons, respectively. These results are in agreement with those of Mohamed *et al*. (2008) who reported that nitrogen rate had a significant effect on number of kernel/ear. These results disagree with those of Yilmaz and Karaaltin (2005) who stated that nitrogen had no significant effects on number of kernels/ear.

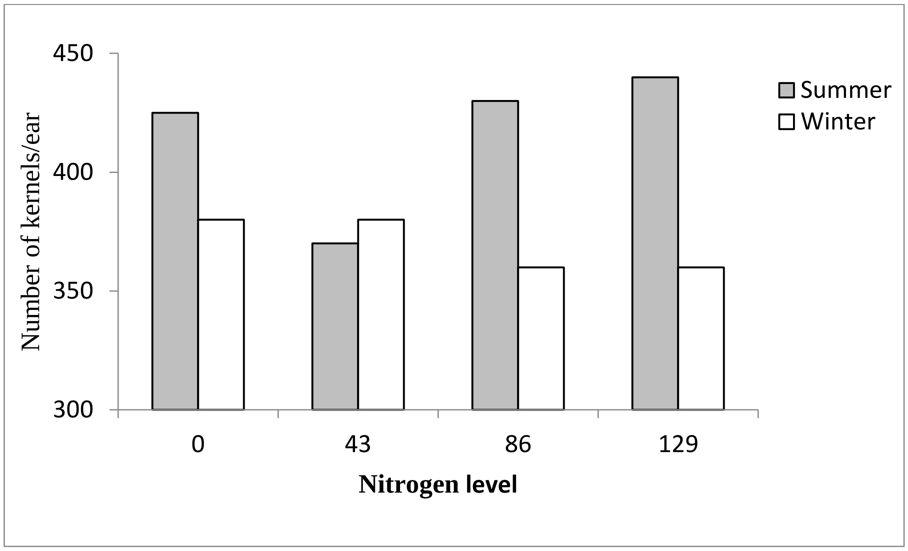

Fig. 1. Effect of nitrogen levels on number of kernels/ear of two maize cultivars during summer and winter seasons (2016/17).

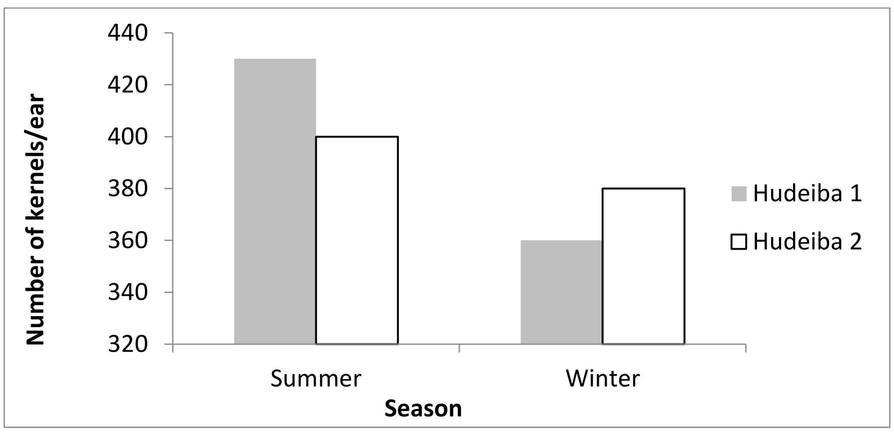

Fig. 2. Number of kernels/ear of two maize cultivars at summer and winter seasons (2016/17).

Grain yield (t/ha)

Effect of nitrogen levels on grain yield of the two maize cultivars in summer and winter seasons is presented in Table 4. Nitrogen had a significant ($P \leq 0.05$) effect on grain yield in both seasons. The highest grain yield (2.4 and 2.1 t/ha) was obtained when 86 kg N/ha were applied in summer and winter seasons, respectively. Cultivars had no significant effect on grain yield in both seasons. The interaction effect of nitrogen levels and cultivars had a significant ($P \leq 0.05$) effect on grain yield in both seasons. The highest grain yield (2.71 and 2.34 t/ha) was obtained when 86 kg N/ha was applied to Hudeiba1 and Hudeiba 2 in summer and winter seasons, respectively. An increase in grain yield as a result of nitrogen levels could be due to the high number of rows/ear. Hudeiba 2 showed better performance with regard to grain yield and yield components in the winter as compared with summer season. This could be explained by the fact that growth conditions in the winter were more favorable for this cultivar.

These results confirmed those of Mohamed *et al*. (2008), Halvorson *et al*. (2006) and Mahdi and David (2005) who reported that maize grain yield significantly increased by increasing nitrogen levels . Similar results were obtained by Mohamed *et al*. (2008) who concluded that both Hudeiba1 and Hudeiba2 were not significantly different in their grain yield. Based on the results of this study, to maximize grain yield of maize, it could be recommended that 86 kg N/ha should be applied to both Hudeiba1 and Hudeiba2 during both seasons.

Table 4. Effect of nitrogen levels on grain yield (t/ha) of two maize cultivars during the summer and winter seasons (2016/ 17).

Nitrogen level (kg/ha)	Hudeiba1	Hudeiba2	Mean
	Summer season		
0	2.01b	1.41c	1.7B
43	1.05c	1.88b	1.5B
86	2.71a	2.09b	2.4A
129	2.07b	2.05b	2.1A
Mean	1.95A	1.80A	1.92
SE± (interaction)	0.26		
CV%	13.5		
	Winter season		
0	1.33d	1.80b	1.5B
43	2.04a	1.81b	1.9A
86	1.90ab	2.34a	2.1A
129	1.58c	1.66c	1.6B
Mean	1.7A	1.9A	1.7
SE± (interaction)	0.2		
CV%	15.6		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

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ولاية الجزيرة، السودان(*Zea mays* L.)تأثير التسميد النتروجيني والصنف على نمو وانتاجية حبوب الذرة الشامية

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الخلاصة

محصول الذرة الشامية هو ثالث محصول عالمي يتصدر محاصيل الغلال بعد القمح والأرز. وفي العقدين الأخيرين أصبح أكثر أهمية في السودان كمحصول غذاء وعلف. تهدف هذه الدراسة إلى تحديد الجرعة المثلى للسماد النتروجينى لزيادة معدل إنتاج محصول الذرة الشامية. أجريت هذه الدراسة بالمزرعة التجريبية جامعة الجزيرة في موسمي صيف وشتاء (2017/2016) تم استخدام صنفي الذرة الشامية حديبة1 وحديبة 2, بتصميم القطاعات العشوائية الكاملة, بثلاث مكررات. استعملت أربعة مستويات من النتروجين (صفر و43 و86 و129 كجم نتروجين/هكتار) ليكون العدد الكلي ثمانية معاملات. أوضحت النتائج ان النتروجين له تأثيراً معنوياً على دليل مساحة الورقة وعدد أيام الإزهار للزهرة المؤنثة وعدد الصفوف في الكوز في موسم الشتاء فقط وكان له تأثيراً معنويا على عدد الحبوب في الكوز في فصل الصيف فقط. كما أظهرت الأصناف تأثيراً معنوياً على عدد الحبوب في الكوز وعدد أيام الأزهار للزهرة المؤنثة في موسمي الصيف والشتاء على التوالي. النتروجين كان له أثراً معنوياً على إنتاجية الحبوب في كلا الموسمين, تحققت أعلى إنتاجية من الحبوب (2.4 و2.1 طن/هكتار) عند إضافة 86 كجم نتروجين/هكتار في فصلي الصيف والشتاء لحديبة 1 وحديبة 2 على التوالي. بناءً على هذه النتائج لتحقيق أعلى إنتاجية من حبوب الذرة الشامية توصي الدراسة بإضافة 86 كجم نتروجين/هكتار لصنفي حديبة 1 وحديبة 2 في كلا الموسمين.