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

Ibrahim E. Mohamed[1], Hussam F. Kareem[2], Ali S. Gangi[1] and Ahmed E. Daffalla[1]

[1]Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan.
[2]Faculty of Agriculture, University of Anbar, Baghdad, Iraq.

ABSTRACT

Maize (*Zea mays* L.) is an annual, cross-pollinated warm weather crop. It is the world's third leading cereal crop after wheat and rice. Recently, 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 and phosphorus to maximize grain yield of maize. This study was conducted at the Experimental Farm, Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017/18. A randomized complete block design with four replicates was used. Four nitrogen levels, namely, 0, 43, 86 and 129 kg N/ha and two phosphorus levels, 0 and 43 P_2O_5 kg/ha were used. Results showed that nitrogen significantly increased plant height, leaf area index, days to 80% tasseling, number of grains/ear and grain yield in both seasons. Nitrogen levels had a significant effect on days to 80% silking in the winter season only. Phosphorus had no significant effect on most of the parameters measured in this study. The interaction between nitrogen and phosphorus levels had a significant effect on plant height, days to 80% silking, number of grains/ear and 100 - grain weight in the winter season only. The results revealed that the interaction between N and P levels had a significant effect on grain yield in both seasons. The highest grain yield (3825 and 4401 kg/ha) was obtained by the application of 129 and 86 kg N/ha in the summer and winter seasons, respectively. To obtain high grain yield of maize, it is recommended to apply 129 and 86 kg N / ha in the summer and winter seasons, respectively, without phosphorus application.

INTRODUCTION

Maize (*Zea mays* L.) is an annual, cross-pollinated warm weather crop. It belongs to the family Poaceae. Two thirds of the world maize production is consumed as a primary staple food in tropical and sub-tropical countries, especially the white dent types. In some regions, the per capita consumption of maize amounted to about 100 kg per year which exceeded that of rice (81 kg/year) and wheat (45 kg/year) (Mohammed *et al*., 2008). In the Sudan, maize is very popular in Nuba Mountains and Blue Nile State, where the crop is grown as a subsistent rain- fed crop.

As a grain crop, maize is a rich source of many important nutrients. Maize grains are useful raw material in industries for the production of medicines and different food recipes (Oladejo and Adetunji, 2012). Maize is also used on a large scale in agro-industries for manufacturing of corn oil, corn flakes and corn sugar (Harris *et al*., 2007).

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 pH ranges of 5 to 7 (Romain, 2001). The soils in the central clay plains of the Sudan, where maize can extensively be grown are mainly Vertisols. These soils are heavy-textured, cracking soils with low amount of organic matter, low total nitrogen and available phosphorus. Nitrogen and phosphorus are the most limiting nutrients for crops in these soils.

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 mainly attributed to low plant density and low levels of inputs used especially fertilizers (Romain, 2001). Maize, like many cereal crops, requires certain quantities of some elements such as nitrogen, phosphorus and potassium for maintaining good yields..

Maize is the best crop having higher potential than other cereals and absorbs a large quantity of nutrients from the soil during different growth stages. Among the basic nutrients, nitrogen and phosphorus are the most important nutrients absorbed by maize to maintain high yield.

In the Sudan, maize gained more importance as a food and forge crop, and the total cultivated area was estimated to be about 169000 ha (FAO, 2003). The average grain yield of the world (7471 kg/ha) is about ten folds that of Sudan due to biotic and abiotic stresses and lack of improved cultural practices , such as seed bed preparation , sowing time and fertilization. In fact, research on maize production has received great attention due to its multipurpose advantages. Therefore, the objective of this study was to investigate the effect of nitrogen and phosphorus levels on growth and grain yield of maize under the conditions of Gezira State, Sudan.

MATERIALS AND METHODS

Field experiments were conducted for two consecutive seasons, summer of 2017 and winter of 2017/18, 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 – 8.4, nitrogen 0.03% and available phosphorus from 4– 6 mg/kg soil. The soil is non-saline and non-sodic. Treatments consisted of 4 levels of nitrogen (0, 43, 86 and 129 kg N/ha) in the form of urea and two levels of phosphorus (0 and 43 kg P_2O_5/ha) in form of super phosphate. A randomized complete block design with four replicates was used. The plot size was 4 x 3.5 m (14 m^2). Hudeiba-2 cultivar was used, the seeds of which were provided by the Agricultural Research Corporation.

The experimental site was disc ploughed, harrowed, leveled and ridged 80 cm apart. Seeds were sown in holes 25 cm apart on the 13th of July 2017 (summer sowing) and the 18th of November 2017 (winter sowing). Three seeds were sown per hole. Irrigation was applied immediately after sowing to ensure adequate crop establishment. Subsequent irrigations were given every 10–14 days. Two to three weeks after sowing, plants were thinned to one plant per hole. Nitrogen fertilizers in form of urea were broadcast and phosphorus was side dressed on top of the ridge about 5 cm away from the seeds. Both fertilizers were applied manually at sowing. Weeds were manually removed at two, three and six weeks after sowing.

The following growth and yield attributes were measured: plant height (cm), leaf area index (LAI), days to 80% tasseling, days to 80% silking, number of grains/ear, 100 grain weight (g) and grain yield (kg/ha). The data were statistically analyzed using the standard analysis of variance procedure and means separation was done using the least significant difference (LSD).

RESULTS AND DISCUSSION

Plant height (cm)

Effect of nitrogen and phosphorus levels and their interaction on maize plant height during the summer and winter seasons are presented in Table 1.

Table1. Effect of nitrogen and phosphorus levels and their interaction on plant height (cm) of maize grown at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017 / 18.

Nitrogen levels (kg/ha)	Phosphorus (P_2O_5) (kg/ha) 0	43	Mean (N)
	Summer season		
0	110.9 a	91.3 a	101.1 B
43	106.8a	122.2 a	114.4 A
86	120.8 a	120.8 a	120.8 A
129	117.0 a	119.2 a	118.1 A
Mean (P)	113.9 A	113.4 A	
SE±	13.5		
CV%	11.8		
	Winter season		
0	106.5 b	84.8 b	95.6 B
43	113.8 b	123.7 a	118.8 A
86	11.8 b	124.7 a	118.3 A
129	140.3 a	137.2 a	138.8 A
Mean (P)	108.1 A	117.6 A	
SE±	7.6		
CV%	6.4		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to the least significant difference (LSD) test.

The interaction between nitrogen and phosphorus levels had a significant effect on plant height during the winter season only. The tallest plants (122.2 and 140.3 cm) were obtained when 43 and 129 kg N/ha coupled with 43 and 0 kg P_2O_5/ha were applied during the summer and winter seasons, respectively. These results were in agreement with those of EL-Douby *et al*. (2000) who concluded that increased nitrogen levels up to 140 kg per fed increased plant height of maize. However, contradicting results were obtained by Rasheed *et al*. (2004) who found that increasing nitrogen application had no significant effect on plant height of maize.

Leaf area index (LAI)

Nitrogen levels had a significant ($P \leq 0.05$) effect on leaf area index (LAI) in both seasons. The largest LAI (3.6 and 3.4) were obtained when 86 kg N / ha and 129 kg N/ ha were applied during the summer and winter seasons, respectively (Table 2).

These results were in line with those of Workayehu (2000) who reported that application of nitrogen fertilizer increased leaf area development in maize which increased photosynthetic activity of the leaf. Monneveux *et al.* (2005) reported that nitrogen deprivation reduced leaf area index, leaf area duration, radiation interceptions, and radiation use efficiency.

Days to 80% tasseling

The interaction between nitrogen and phosphorus levels had a significant (P≤0.05) effect on days to 80% tasseling in both seasons. The highest number of days to 80% tasseling (68 and 88 days) were obtained when zero kg of both N and P were applied in both seasons (Figs. 1 and 2).

Table 2. Effect of nitrogen and phosphorus levels and their interaction on Leaf area index (LAI) of maize grown at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017/ 18.

Summer season			
Nitrogen levels (kg/ha)	Phosphorus (P_2O_5) (kg/ha)		Mean (N)
	0	43	
0	2.4 a	2.1 a	2.3 B
43	3.0 a	3.0 a	3.1A
86	3.8 a	3.5 a	3.6A
129	2.9 a	2.8 a	2.9 AB
Mean (P)	3.1 A	2.9 A	
SE±	0.61		
CV%	20.7		
Winter season			
0	2.6 a	2.1 a	2.4 B
43	2.4 a	2.8 a	2.6 A
86	2.9 a	3.0 a	2.8 A
129	3.2 a	3.6 a	3.4 A
Mean (P)	2.1 A	2.9 A	
SE±	0.50		
CV%	17.8		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to the least significant difference (LSD) test.

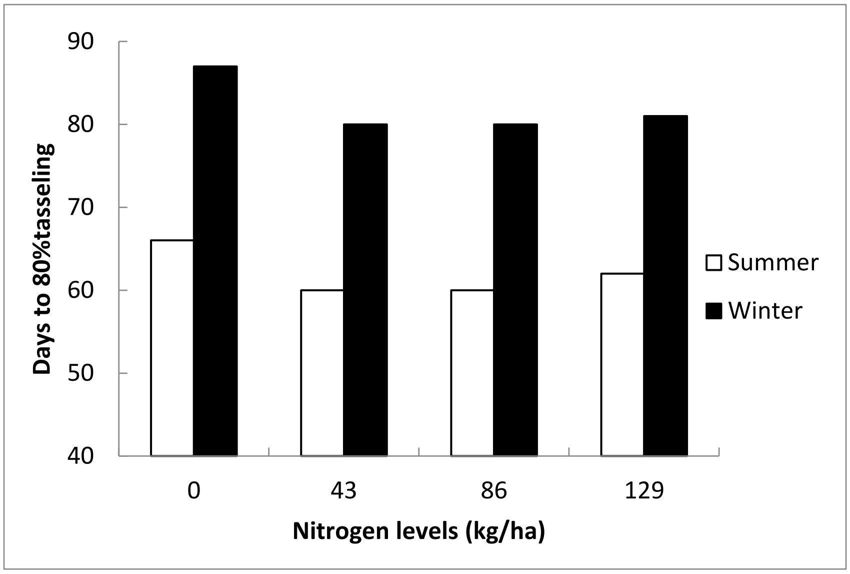

Fig.1. Effect of nitrogen levels on number of days to 80% tasseling in maize during summer of 2017 and winter season of 2017/18.

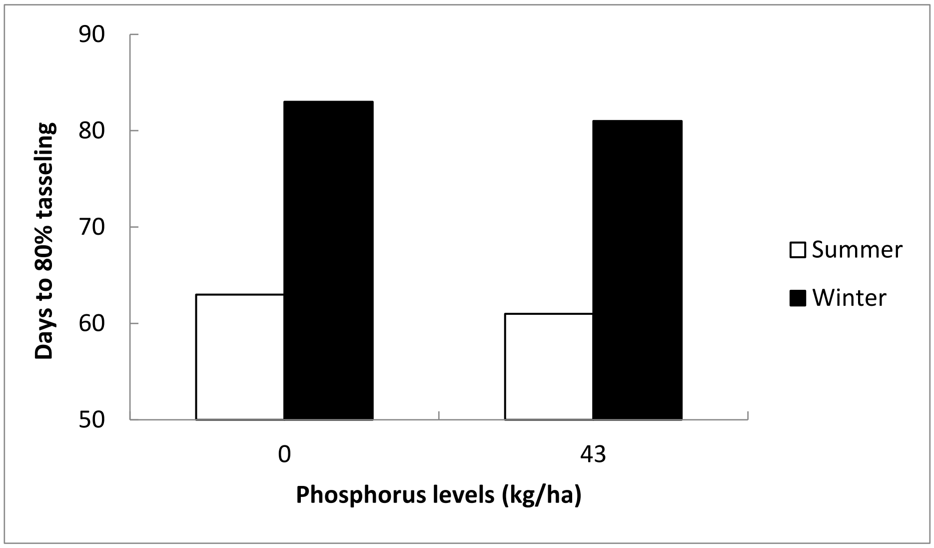

Fig. 2. Effect of phosphorus levels on number of days to 80% tasseling in maize during summer of 2017 and winter season of 2017/18.

These results disagree with those of Bakht *et al*. (2006) who reported that increasing nitrogen level significantly ($P \leq 0.05$) increased days to 50% tasseling, while these results were in line with those of Akbar (2003) who reported that zero nitrogen application increased days to 50% tasseling.

Days to 80% silking

Effect of nitrogen and phosphorus levels and their interaction on days to silking during the summer and winter seasons is presented in Figs. 3 and 4.

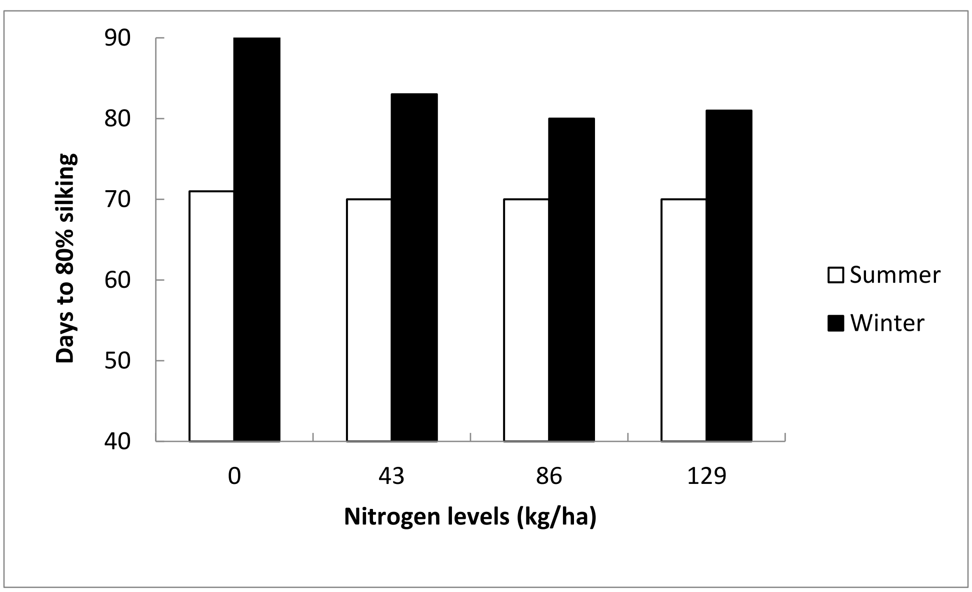

Fig. 3. Effect of nitrogen levels on number of days to 80% silking in maize during summer of 2017 and winter season of 2017/18.

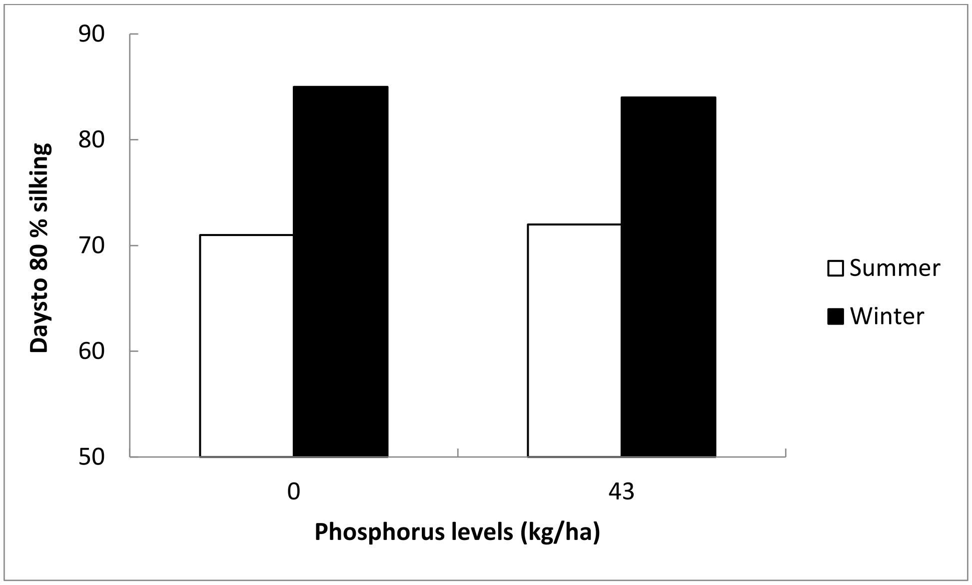

Fig.4. Effect of phosphorus levels on number of days to 80% silking in maize during summer of 2017 and winter season of 2017/18.

The interaction between nitrogen and phosphorus levels had a significant ($P \leq 0.05$) effect on days to silking of maize in winter season only. The highest number of days to 80% silking (74 and 98) were obtained when zero nitrogen and phosphorus were applied during both seasons. Similar results were obtained by Akbar (2003) who reported that zero nitrogen significantly increased days to silking. Monneveux *et al.* (2005) reported that zero nitrogen increased time to anthesis (silking). These results disagreed with those of Bakht *et al*. (2006) who stated that increasing nitrogen level significantly increased days to 50% silking.

Number of grains/ear

Effect of nitrogen and phosphorus levels and their interaction on number of grains/ear during the summer and winter seasons are presented in Table 3.

Table 3. Effect of nitrogen and phosphorus levels and their interaction on number of grains/ear of maize grown at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017/ 18.

Nitrogen levels (kg / ha)	Phosphorus (P_2O_5) (kg/ha) 0	43	Mean (N)
Summer season			
0	197 a	231 a	214 B
43	270 a	301 a	285A
86	305 a	297 a	301 A
129	312 a	345 a	328 A
Mean (P)	271 A	293.5 A	
SE±	169.6		
CV%	24.7		
Winter season			
0	379b	375ab	377 B
43	415a	319 b	367 B
86	414a	460 a	437 A
129	492a	486a	489 A
Mean (P)	425 A	410 A	
SE±	33.08		
CV%	7.9		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to the least significant difference (LSD) test.

Nitrogen levels had significant ($P \leq 0.05$) effect on number of grains/ear in both seasons. The highest number of grains/ear 328 and 489 was obtained when 129 kg N/ha was applied in the summer and winter seasons, respectively. Phosphorus levels had no significant ($P \leq 0.05$) effect on number of grains/ear of maize in both seasons. The interaction between nitrogen and phosphorus levels had significant effect on number of grains/ear in the winter season only. The highest number of grains/ear (345 and 492) was obtained when 129 kg N/ha coupled with 43 and zero phosphorus levels were applied in the summer and winter seasons, respectively.

These results were in line with the findings of Bakht *et al.* (2006) who stated that increasing nitrogen levels enhanced final seed yield due to the increase in the number of seeds per ear. Jalali *et al.* (2010) recorded that application of urea fertilizer up to 250 kg/ha resulted in the highest number of grains/ear.

Mehmood and Saeed (1998) reported that lower nitrogen levels had suppressive effect on number of grains/ear as nitrogen plays a central role in grain formation.

100- grains weight (g)

Effect of nitrogen and phosphorus levels and their interaction on 100 grains weight during the summer and winter seasons are presented in Table 4. Phosphorus levels had a significant effect on 100-grains weight in both seasons. The interaction between nitrogen and phosphorus levels had a significant ($P \leq 0.05$) effect on 100 grains weight of maize in the winter season only. The heaviest grains (26.4 and 26.9 g) were obtained when 43 and zero kg N/ha coupled with 43 and zero P_2O_5were applied in the summer and winter seasons, respectively. These results were in agreement with Kogbe and Adriran (2003) who reported that phosphorus application significantly affected the 100 grain weight of maize. However, Ali (1997) stated that application of 43 kg P_2O_5/ ha obtained the heaviest 100 grain weight. The same author concluded that the addition of 43 kg P_2O_5 / ha was economically better than 86 P_2O_5 /ha with regard to the grain weight of maize.

Grain yield (kg/ha)

The interaction between nitrogen and phosphorus levels had a significant ($P \leq 0.05$) effect on grain yield of maize in both seasons. The highest grain yield (3825 and 4401 kg /ha) was obtained when 129 and 86 kg N/ha coupled with zero and 43 P_2O_5 were applied in the summer and winter seasons, respectively (Table 5).

Generally, grain yield of maize was higher in winter than in summer. This could be due to the favorable conditions which were reflected in the vigorous vegetative growth of the crop in the winter compared with the summer crop. Grain yield of maize was significantly increased with increasing nitrogen levels from zero to 129 kg N/ha in both seasons. This increase in grain yield could be explained by the increase in number of grains per ear and the heaviest grain weight in response to the increment of nitrogen and phosphorus. These results confirmed the findings of Huseyin and Konukan (2010) who stated that grain yield increased by N application up to 240 kg N /ha. However, Hussain *et al.* (2018), in the Sudan, concluded that the highest grain yield of maize was obtained by the application of 86 kg N/ha. Bakht *et al.* (2006) showed that increasing N levels enhanced final seed yield due to the increase in number of seeds per ear. Phosphorus levels had no significant effect on grain yield of maize in both seasons. This could be explained by the fact that phosphorus levels in the soil were adequate for maize plants and, hence, there was no response for applied phosphorus. These results disagree with those of Khan *et al.* (1999) who reported that grain yield of maize was significantly affected by the application of phosphorus. Based on these results, to obtain high grain yield of maize, it could be recommended to apply 129 and 86 kg N/ha in the summer and winter seasons, respectively without phosphorus application.

Table 4. Effect of nitrogen and phosphorus levels and their interaction on 100 grains weight of maize grown at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017/ 18.

Nitrogen levels (kg/ha)	Phosphorus (P_2O_5) (kg / ha) 0	43	Mean (N)
	Summer season		
0	17.4 a	26.1 a	22 A
43	22.3 a	26.4 a	.24 A
86	24.2 a	23.6 a	24 A
129	23.5 a	26.2 a	25 A
Mean (P)	22 B	26 A	
SE±	4.46		
CV%	18.8		
	Winter season		
0	26.9 a	15.4 b	21 A
43	18.7 b	20.2 a	19 A
86	23.2 a	21.3 a	22 A
129	22.9 a	18.0 a	20 A
Mean (P)	22 A	19 B	
SE±	2.01		
CV%	9.6		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to the least significant difference (LSD) test.

Table 5. Effect of nitrogen and phosphorus levels and their interaction on grain yield (kg/ha) of maize grown at the experimental farm of the Faculty of Agricultural Sciences, University of Gezira, during the summer of 2017 and winter season of 2017/ 18.

Summer season			
Nitrogen levels (kg / ha)	Phosphorus (P_2O_5) (kg / ha)		Mean (N)
	0	43	
0	1446 b	2253 a	1849.5 B
43	2236 b	2698 a	2467 AB
86	2946 a	2434 a	2690 AB
129	3825 a	2981 a	3403 A
Mean (P)	2613 A	2591.5 A	
SE±	408.3		
CV%	15.7		
Winter season			
0	2894 a	2397 b	2646 B
43	2289 a	3477 a	2883 A
86	2858 a	4401 a	3629 A
129	3433 a	3747 a	3590 A
Mean (P)	2868.5 A	3505.5 A	
SE±	432.9		
CV%	13.6		

Means followed by the same letter(s) are not significantly different at 5% level of probability according to the least significant difference (LSD) test.

ACKNOWLEDGEMENT

This work was funded by the Ministry of Higher Education and Scientific Research of the Sudan.. The authors would like to express their deepest appreciation for this generous fund.

REFERENCES

Akbar, H. 2003. Carry Over Effect of Crop Management Techniques and Nitrogen on the Yield of Maize. Ph.D. Thesis, Faculty of Crop Production Sciences, NWFP Agricultural University, Pakistan.

Ali, F.M. 1997. Principles of Maize (*Zea mays* L.) Production . ARC, Wad Medani, Sudan (in Arabic).

Bakht, J., M. Faisal Siddique, M. Shaft, Habib Akbar, M. Tariq, Nazir Khan, M. Zubair and M. Yousef. 2007. Effect of planting methods and nitrogen levels on the yield and yield components of maize. ***Sarhad Journal of Agriculture 23 (3):*** 8 – 14.

El-Douby, K.A., E. A. Ali, S.E.A. Toaima and A.M. Abdel Aziz.2000. Response of maize to nitrogen fertilization. Field Crop Research Institute, Agricultural Research Centre, Giza, Egypt.

FAO. 2003. Food and Agriculture Organization of the United Nations. Production Year Book,. Rome, Italy.

Harris, A., G. Miraj, M. Arif and H. Shah. 2007. On-farm seed priming with zinc sulphate solution, a cost-effective way to increase the maize yields of resource-poor farmers. Field Crops Research 110: 119–127.

Huseyin G. and O. Konukan. 2010. Nitrogen dose and plant density effects on popcorn grain yield. African Journal of Biotechnology 9 (25):3828-3832.

Hussain, A.A.M., I.E. Mohamed and A.E.Daffalla. 2018. Effect of nitrogen fertilization and cultivar on growth and grain yield of maize (*Zea mays* L.), Gezira State, Sudan. Gezira Journal of Agricultural Science 16 (1): 41-52.

Jalali, A.M., M.J. Bahrani and F. Salehi. 2010. Yield of corn (*Zea mays* L.), organic carbon changes and nitrate nitrogen of soil under effect of compost application, residues and nitrogen fertilizer management. Proceeding of 11th Iranian Crop Science Congress.

Khan, M.A., M.U. Khan, K. Ahmad and M. Sadiq. 1999. Yield of maize hybrid-3335 as affected by NP levels. Pakistan Journal of Biological Science 2: 857-859.

Kogbe, J.O.S. and J.A. Adriran. 2003. Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savanna zone of Nigeria. African Journal of Biology 2: 345-349.

Mehmood, T. and M. Saeed. 1998. Nitrogen level and plant density effects on different agrophysiological traits of maize. Pakistan Journal of Biological Science 1(4):259-263.

Mohamed, A.A., A.E.S. Ibrahim, A.S. Gangi and E.S. Ali. 2008. Effect of cultivar and plant population on grain yield of maize (*Zea mays* L.) in River Nile State. Gezira Journal of Agricultural Science 6 (2): 268-274.

Monneveux, P.P., H. Zaidiand and C. Sanchez. 2005. Population density and low nitrogen affects yield-associated traits in tropical maize. Crop Science 45: 535-545.

Oladejo, J.A. and M.O. Adetunji. 2012. Economic analysis of maize *(Zea mays* L.) production in Oyo State of Nigeria. Agricultural Science Research Journal 2(2): 77-83.

Rasheed, M., H. Ali and T. Mahmood. 2004. Impact of nitrogen and sulfur application on growth and yield of maize (*Zea mays* L.) Crop Journal of Research Science 15 (2) :153-157.

Romain, H.R. 2001. Crop production in Africa. Directorate General for International Cooperation (DGIC). Brussels. Belgium 165-187.

Workayehu, T. 2000. Effect of nitrogen fertilizer and plant density on grain yield of maize. African Crop Science Journal 8 (3): 273- 282.

تأثير مستويات النتروجين والفوسفور على نمو وإنتاجية حبوب الذرة الشامية (*Zea mays* L.)، ولاية الجزيرة، السودان

إبراهيم البشير محمد[1] وحسام فيصل كريم[2] وعلى صالح جانقي[1] وأحمد الطيب دفع الله[1]

[1]كلية العلوم الزراعية، جامعة الجزيرة، واد مدني، السودان.

[2]كلية الزراعة، جامعة الأنبار، بغداد ، العراق.

الخلاصة

الذرة الشامية محصول حولي، خلطي التلقيح ومن محاصيل الجو الدافئ. الذرة الشامية ثالث أهم محاصيل الحبوب في العالم بعد القمح والأرز. حديثاً اكتسب الذرة الشامية أهمية كبيرة كمحصول غذاء وعلف في السودان. تهدف هذه الدراسة لتحديد تأثير مستويات النتروجين والفسفور على نمو وإنتاجية حبوب الذرة الشامية. نفذت الدراسة في المزرعة التجريبية كلية العلوم الزراعية, جامعة الجزيرة، وادمدني، السودان خلال موسمي صيف 2017 وشتاء 18/2017. تم استخدام نظام القطاعات العشوائية الكاملة بأربع مكررات. اشتمل النتروجين على 4 معاملات (0, 43, 86, 129 كجم نتروجين/هكتار) والفسفور معاملتان (0, 43 كجم خامس أكسيد الفسفور/هكتار). أظهرت النتائج أن إضافة النتروجين أدت إلى زيادة معنوية في طول النبات ودليل مساحة الورقة وعدد الايام 80% زهرة مذكرة وعدد الحبوب في الكوز وانتاجية الحبوب في الموسمين. كما أن إضافة النتروجين كان لها تأثيراً معنوياً على عدد الايام 80% زهرة مؤنثة خلال الموسم الشتوي فقط. لم يكن لإضافة الفسفور أي تأثير معنوي علي معظم المؤشرات التي تمت دراستها. التداخل بين مستويات النتروجين والفسفور كان لها تأثيراً معنوياً على طول النبات وعدد الايام 80 % زهرة مؤنثة وعدد الحبوب في الكوز ووزن 100 حبة في فصل الشتاء فقط. أظهرت النتائج أن التداخل بين مستويات النتروجين والفسفور كان له تأثيراً معنوياً على إنتاجية الحبوب خلال الموسمين، أعلى انتاجية (3825 و 4401 كجم/هكتار) تحققت عند إضافة 129 و 86 كجم/هكتار في الصيف والشتاء على التوالي. لتحقيق إنتاجية عالية من حبوب الذرة الشامية توصى الدراسة بإضافة 129 و 86 كجم نتروجين/هكتار في موسمي الصيف والشتاء على التوالي بدون إضافة الفسفور.