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Growth and productivity of maize (*zea mays* l.) As affected by nitrogen and zinc fertilizer levels: 1. Growth analysis

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Growth analysis of maize (*Zea mays* L.) cv. single cross 10 as affected by three nitrogen levels, i.e. 100, 120 and 140 kg N/fed. (one feddan = 4200 m^2) and three zinc levels (0, 10 and 20 kg/fed.) were studied. Experiments were conducted at the Agricultural and Experiments Research Station at Giza, Faculty of Agriculture, Cairo University, Egypt during two successive summer seasons 2016 and 2017. The experiments design was split- plot in randomized complete block design with three replications. Results showed that increasing N levels up to 120 kg N/fed. Significantly increased LA/ plant, LAI, CGR in both seasons and NAR in one season. Whereas, RGR, LA/ topmost ear in both seasons and NAR in one season were significantly increased with increasing N levels up 140 kg N/fed. As regarding to zinc effect, there was significant effect on all studied growth characters in both seasons except RGR, NAR and LA/ topmost ear in one season. The interaction between the two studied factors had significant effect on CCR and NAR in both seasons and RGR in one season. The highest NAR in 2016 and CGR in 2017 were recorded at 120 kg N/fed + 20 kg Zn/fed. Treatment, while the highest RGR in 2016 and NAR in 2017 was obtained at 140 kg N/fed. +10 kg Zn/fed. Treatment.

Keywords: Maize, growth analysis, Nitrogen, Zinc.

INTRODUCTION

Maize (*Zea mays* L.) known in much of the world as corn, is the world's third most important cereal after wheat and rice. Maize is grown primarily for grains and secondary for food and row materials for industrial processes. In Egypt maize mostly grown in the most governorates, being cultivated area of 1039241 hectares giving annual production of 8059906 tones with average yield of 7.8 t/ha (FAO, 2016). The maize crop requires adequate supply of nutrients particularly nitrogen and zinc for good and high yield. Nitrogen and zinc are very essential for good vegetative growth and grain development in maize production. Nitrogen is a component of protoplasm, proteins, nucleic acid, chlorophyll and play a vital role in vegetative and productive phases of crop growth. Higher nitrogen levels are reported to increase plant height (PH), leaf area (LA), leaf are index (LAI), dry matter (DM), net assimilation rate (NAR), relative growth rate (RGR), crop growth rate (CGR) and grain yield per unit area (AL-Shebani, 1998 and 2002 ; Nemati and Sarifi, 2012; Mondita Jena et al., 2013, Ullah et al., 2015 ; Hafez and Abdellaa , 2016). Maize also needs some micronutrients for its better growth and higher yield such as zinc. Zinc plays a very important role in plant growth. Zinc required in small quantity for crop but if there is zinc deficient then it can withhold plant growth. It is used in form of zinc sulfate ($ZnSO_4$) fertilizer because zinc sulfate have higher rate of solvency. Mohsin et al. (2014) reported that application of zinc significantly increased growth characters such as LA/ plant, LAI, LAD, CGR and NAR. However, uses of nitrogen fertilizer along with other nutrients such as zinc have been suggested to enhance the growth and crop productivity. It is a well-established fact that plant structure is determined by growth parameter such as DMA, RGR, LA/plant, LAI, CGR, RGR, NAR and relative chlorophyll content (Gheith et al. , 2013). The use of the above mentioned growth parameter to analysis' quantity plant growth had become known as growth analysis (Watson, 1952). Keeping in view the above facts, the present study was conducted to investigate the effect of different nitrogen and zinc fertilizer levels on growth analysis of maize

MATERIALS AND METHODS

A split plot experiment based on randomized complete plock design with three replications was conducted at the Agricultural and Experiments Research Station at Giza, Faculty of Agriculture, Cairo university, Egypt during the successive summer seasons 2016 and 2017 to study the effect of three nitrogen levels, i.e. 100, 120 and 140 kg N/fed. (one feddan =4200 m^2) and three zinc levels (0, 10 and 20 kg /fed.). On growth analysis of maize (*Zea mays* L.) cv. single cross 10. Nitrogen fertilizer levels were arranged in main plots and zinc fertilizer levels were in sub plots. In each plot there were 5 ridges (2 m long and 70 cm apart). Maize grains were planted in the third and second week of May in the first and second season, respectively. The grains were sown per hill (25 cm apart) and latter thinned to one plant/hill. Thinning was done before the first irrigation (18 days after planting). Nitrogen fertilizer (urea 46%. N) and zinc fertilizer ($ZnSO_4$) were applied together in two equal splits, the first dose was applied before the first irrigation and the second one was added before the second irrigation. All other agronomic operations except those under study were kept normal and uniform for all treatments. Growth analysis was determined at 70 and 85 days from planting on five plants basis randomly taken from each sub plot. Samples were carried out to the laboratory and were separated into leaves and stems. Plant materials were dried in a ventilated oven to the constant weight for 48 hours at 70 centigrade to determine the dry matter. Data collection procedure for the following parameters is as under:

Leaf area/plant (LA/plant) = leaf length × leaf width × 0.75 × number of green leaves/plant cm^2

Leaf area index (LAI) = Leaf area / plant (cm^2) /plant ground area (cm^2).

Crop growth rate (CGR) = W_2 - W_1 / T_2 - T_1 × 1 / GA g/m^2/day.

Relative growth rate (RGR) = L_nW_2 - L_nW_1 / T_2 - T_1 mg/g/day.

Net assimilation rate (NAR) = (W_2 - W_1) (L_nLA_2 - L_nLA_1) / (T_2 - T_1) (LA_2 - LA_1) mg/dm^2/day.

Where: W_1, LA_1 and W_2, LA_2 refer to plant dry weight and leaf area per plant at T_1 and T_2 time of sampling, respectively. Whereas, GA= ground area and Ln (X) = 2.303 × log (X).

LA/plant and LA/ topmost ear were determined using method described by Pearce et al. 1975, while CGR, RGR and NAR were calculated according to Watson formula (Radford, 1967). The recorded data were analyzed statistically by using statistical software package MSTAT-C (Michigan State University, 1990). Least significantly a difference (L.S.D.) at 0.05 % probability was employed to test the significant differences among mean values of each treatment (Steet and Torrie, 1997).

RESULTS AND DISCUSSION

Effect of nitrogen fertilizer levels

Results presented in (Table 1 and 2) showed that nitrogen fertilizer levels significantly affected leaf area/plant (LA/plant) at 70 and 85 days, leaf area index (LAI) at 85 days, crop growth rate (CGR), relative growth rate (RGR), net assimilation rat (NAR) and leaf area/topmost ear (LA/TE) at 85 days in both seasons. This effect was not true on LAI at 70 days in the first season. Increasing N levels up to 120 kg N/fed. caused significant increase in LA/plant at 70 and 85 days, LAI at 70 and 85 days in both seasons and NAR in the first season. On the other hand, increasing N levels up to 140 kg N/fed. significantly increased RGR and LA/topmost ear in both seasons and NAR in the second season. These results expected that nitrogen is one of the most important components of cytoplasm, nucleic acid and chlorophyll. Therefore, as the levels of nitrogen increased rapid multiplication of cells occur which in turn enhanced the amount of metabolism necessary for building plant organs. The present results are in harmony with those obtained by several investigators who recorded that increasing N levels significantly increased

LA/plant (Al-Shebani, 1998 and 2002; Hafez and Abdelaa, 2015; Ullah et al., 2015), LAI and CGR (Cheema et al., 2010; Mondita Jena et al., 2013) and LA/topmost ear (Faisal et al., 1997; Nofal, 1999). On the contrary, Ahmed (1990) found that increasing N levels had no significantly effect on RGR and NAR.

Table 1: Growth analysis of maize as affected by nitrogen fertilizer levels in 2016 Season.

Growth characters	N levels (kg/fed.)				
	100	120	140	F	L.S.D.
LA/Plant (cm^2) at 70 days	69.9	79.1	65.9	*	8.1
LA/Plant (cm^2) at 85 days	74.7	90.5	84.5	*	12.9
LAI at 70 days	4.6	4.6	4.0	ns	
LAI at 85 days	4.8	5.2	4.5	*	2.0
CGR (g/m^2/day) at 85 days	66.9	82.4	76.0	*	6.1
RGR (mg/g/day) at 85 days	25.9	25.7	25.8	*	4.0
NAR (mg/cm^2/days) at 85 days	103.7	148.5	130.5	*	16.6
LA/ topmost ear (cm^2) at 85 days	7.5	8.6	8.8	*	1.4

* = significant and ns = not significant

Table 2: Growth analysis of maize as affected by nitrogen fertilizer levels in 2017 Season.

Growth characters	N levels (kg/fed.)				
	100	120	140	F	L.S.D.
LA/Plant (cm^2) at 70 days	89.1	100.5	69.3	*	8.3
LA/Plant (cm^2) at 85 days	90.9	103.2	98.7	*	7.5
LAI at 70 days	5.1	5.7	5.5	*	0.5
LAI at 85 days	5.2	5.9	5.7	*	0.5
CGR (g/m^2/day) at 85 days	82.9	103.1	136.2	*	28.1
RGR (mg/g/day) at 85 days	34.9	36.3	37.0	*	2.6
NAR (mg/cm^2/days) at 85 days	185.6	236.6	284.1	*	50.9
LA/ topmost ear (cm^2) at 85 days	9.6	10.9	11.5	*	1.2

* = significant

Effect of zinc fertilizer levels

Results presented in Table (3 and 4) showed that LA/plant and LAI at 70 and 85 days and CGR at 85 days were significantly affected by zinc fertilizer levels in both seasons, while this effect was true on RGR, NAR and LA/topmost ear in the second season. Only. The highest LA/plant (85.7 and 99.3 cm^2) at 85 days, LAI (4.2 and 6.4) at 70 days and RGR (27.4 and 36.3 mg/g/day) at 85 days were recorded at 10 kg/fed. in both seasons, respectively. Whereas, LA/plant (73.1 and 104.3 cm^2) at 70 day, CGR (117 and 124 mg/g/day), NAR (126.8 and 275.1 mg/dm^2/day) and LA/topmost ear (9.8 and 11.0 cm^2) at 85 day were observed at 20 kg /fed. in both seasons, respectively. It is evident from these results that the lowest values for all studied parameters, except LA/topmost ear in the first season, were recorded from unfertilized plants (0.0 Zn) in both seasons. The previous results may be due to that Zn is required to healthy growth and life cycle completion (Ali, 2012). It play a role in many function in plant growth and development. This function includes chlorophyll synthesis, enzymatic activities of photosynthesis, synthesizing protein, RNA and DNA (Ali, 2012; Mand et al., 2014). The present results are in agreement with those recorded by Mohsin et al., (2014) who reported that application of Zn significantly improved LA/plant, LAI, LAD, CGR and NAR.

Effect of the interaction

Results in Table (5) indicated that the interaction between N and Zn levels had significant effect on CGR and NAR in both seasons and RGR in the second season. The highest CGR (103.7 and 131.6 mg/m^2/day) was recorded at 120 kg N/fed. + 10 kg Zn/fed. In the both seasons, respectively. As regarding to NAR, the highest value (180.0 mg/cm^2/day) was obtained at 120 kg N/fed. +20 kg Zn/fed. in the first season, and (328.0 mg/cm^2/ day) at 140 kg N/fed. and 20 kg Zn/fed. in the second season. In this way, the highest RGR

(37.3 g/m^2/day) was reported at 140 kg N/fed. and 10 kg Zn/fed. In the second season.

Table 3: Growth analysis of maize as affected by zinc fertilizer levels in 2016 Season.

Growth characters	Zn levels (kg/fed.)				
	0	10	20	F	L.S.D.
LA/Plant (cm^2) at 70 days	69.6	72.8	73.1	*	3.1
LA/Plant (cm^2) at 85 days	78.4	85.7	85.6	*	4.2
LAI at 70 days	3.9	4.2	4.2	*	0.2
LAI at 85 days	4.9	4.5	5.1	*	0.3
CGR (g/m^2/day) at 85 days	68.8	80.0	117.0	*	8.9
RGR (mg/g/day) at 85 days	27.4	27.4	26.8	ns	-
NAR (mg/cm^2/days) at 85 days	126.9	123.9	126.8	ns	-
LA/ topmost ear (cm^2) at 85 days	8.6	8.1	9.8	ns	-

* = significant and ns = not significant

Table 4: Growth analysis of maize as affected by zinc fertilizer levels in 2017 Season.

Growth characters	Zn levels (kg/fed.)				
	0	10	20	F	L.S.D.
LA/Plant (cm^2) at 70 days	97.2	112.4	104.3	*	6.6
LA/Plant (cm^2) at 85 days	90.5	99.3	69.0	*	12.3
LAI at 70 days	5.5	6.4	5.9	*	0.4
LAI at 85 days	5.2	5.7	5.5	*	0.2
CGR (g/m^2/day) at 85 days	93	105.2	124.1	*	30.6
RGR (mg/g/day) at 85 days	35.7	36.8	36.2	*	1.9
NAR (mg/cm^2/days) at 85 days	189.1	242	275.1	*	29.1
LA/ topmost ear (cm^2) at 85 days	10.3	10.8	11.0	*	0.4

* = significant

Table 5: Effect of interaction on CGR, NAR in 2016 and 2017 and RGR in 2017 season.

N levels (kg/fed.)	**Zn levels (kg/fed.)**	**CGR (g/m^2/day)**		**NAR (mg/m^2/day)**		**RGR (mg/g/day)**
		2016	2017	2016	2017	2017
100	0	67.0	67.7	110.0	142.3	34.8
	10	63.3	84.8	90.9	225.3	34.7
	20	70.7	96.3	110.0	189.0	35.7
120	0	69.3	122.6	120.2	128.0	36.3
	10	103.7	131.6	130.3	233.3	36.3
	20	75.3	154.5	180.0	308.3	36.6
140	0	45.0	88.7	150.3	257.0	36.7
	10	89.7	99.2	150.6	267.3	37.3
	20	94.0	121.3	90.5	328.0	37.0
F		*	*	*	*	*
L.S.D.(0.05)		10.5	38.8	25.1	35.9	2.3

* = significant

CONCLUSION

The obtained results indicated that LA/plant, LAI and CGR were increased with increasing N levels up to 120 Kg N/fed, but RGR, NAR and LA/topmost ear were increased with increasing N levels up to 140 kg /fed. As regarding to Zn application, the highest LA/plant at 85 days LAI at 70 and 85 days and RGR were obtained at 10 kg N/fed., whereas the highest LA/plant at 70 days, CGR, NAR and LA/topmost ear were at 20 kg/fed. Application of 120 kg N/fed.+10 kg Zn/fed. are recommended for the obtained higher growth characters under the experimental site and the same conditions.

CONFLICT OF INTEREST

The present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this study.

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