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EFFECT OF WATER REGIME, NITROGEN LEVEL AND ZINC APPLICATION ON MAIZE YIELD AND ITS WATER RELATIONS

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ABSTRACT

A field experiments was carried out at Sakha Agric. Res. Sta. Farm during two successive summer seasons (2002 and 2003) to study the effects of water regime, nitrogen fertilizer levels and zinc application on maize yield and its water relations as well as some soil chemical properties. Split-split plot design with four replicates was used, where 4 water regime treatments (40%, 55%, 70% and 85% depletion of available soil moisture) were occupied the main plots. Nitrogen fertilizer with three levels (90, 110 and 130 kg N fed^{-1}.) were placed in the sub-plots and three zinc treatments (150 ppm zinc-EDTA chelate as a foliar spray application, 10 kg fed^{-1} Zn- sulfate as soil application and without zinc applied) were allocated to sub-sub-plots.

The main results could be summarized as follows:

- There was a significant effect of water regime on maize yield and its components. Irrigation at 55% depletion of available soil moisture (I_2) produced the highest maize yield and its components. While the irrigation at 85% depletion of available soil moisture (I_4) gave the lowest maize yield.
- Increasing nitrogen fertilization level up to 130 kg fed^{-1} highly significantly increased maize yield and its components.
- The foliar application of zinc produced the higher maize yield than the soil applied zinc.
- The highest amount of irrigation water applied and water consumptive use (WCU) were obtained with irrigation at 40% depletion of available soil moisture. While the irrigation at 85% depletion of available soil moisture gave the highest values of crop water use efficiency (CWUE).
- Soil salinity (ECe), soluble ions and SAR were decreased with increasing the amount of irrigation water applied. On the other hand, decreasing the amount of irrigation water applied (I_4 Treat.) led to salts accumulation in the soil profile during both seasons.

Generally, it could be concluded that increasing nitrogen fertilization level up to 130 kg fed^{-1} and irrigation at 55% depletion of available soil moisture with 150 ppm foliar spray of zinc gave the highest maize yield and its components.

Keywords: Maize yield, water regime, nitrogen level and zinc application, water relation.

INTRODUCTION

Maize (*zea mays, L.)*is one of the most important cereal crops in Egypt for human consumption and animal feeding. Productivity of maize plant is affected by many factors. Duration and irrigation timing, water stress and fertilization together with yield potentiality could be considered as the main factors.

Water is often the primary limiting factor for maize production. The greatest decrease in grain yield was caused by water deficits during the flowering stage including tasseling, silking and pollination (El-Kassaby *et al.*, 1985). Therefore, it is necessary to determine the optimum water requirements and the best irrigation management for obtaining the maximum yield. Ragab *et al.* (1986); El-Refai *et al.* (1988); Sadik *et al.* (1995); Ghazy (2002) and Ragab *et al.* (2002) studied the effect of water regime on maize grain yield and its components. They reported that increasing the amount of irrigation water led to increase water consumptive use and significantly increased the maize grain yield and its components. In these connections, they reported that the irrigation at 50 to 55 % depletion of available soil moisture was the suitable irrigation regime for maize. While the maize grain yield was found to be decreased with increasing water stress (Ainer, 1976; Metwally, 1977; Sadik *et al.*, 1995 and Ghazy 2002). On the other hand, high soil moisture content limited root development as a result of insufficient oxygen and lack of nitrate formation (Miller, 1955).

As the level of nitrogen increases, more protein is produced and allows the plant to grow larger surface available for photosynthesis (Russell, 1973). Maize plant is one of the most responding plants to nitrogen and this may be reflected on increasing the plant height, grain yield and protein content (Kandil *et al.*, 1984 and El-Kassaby *et al.,* 1985). Much researches had been carried out to evaluate the optimum level of nitrogen fertilizer required for the maximum yield of maize (Younes *et al.*, 1995; El-Far, 1996; Badawi and El-Moursy, 1997; El-Hamdi *et al.*, 1998; El-Moursy *et al.*, 1998 and Ragab, 1998) they found that increasing nitrogen fertilizer rates from 60 to 220 Kg N/fed. significantly increased maize grain yield and other growth parameters.

Zinc deficiency is one of the main factors affecting strongly the crop production. The susceptibility of crop plants to zinc deficiency varies considerably depending on species and even cultivars. Several forms of zinc fertilizer are available, and their efficiency depend greatly upon placement, soil type and other factors (Soltanpour *et al.,* 1970). El-Khateeb and Selim (1993) found that the application of zinc increased the content of chlorophyll and plant growth of many plants. Srinivasan (1992); Abd El-Salam *et al.* (1994) and Ragab (1998) revealed that the grain yield of maize and its components was increased with zinc fertilizer, especially by foliar application.

The objective of this experiment was to study the effect of water regime, nitrogen fertilizer levels and zinc application on maize yield and its water relations and some soil chemical properties.

MATERIALS AND METHODS

A field experiments was carried out at Sakha Agric. Res. St. Farm during the two successive summer seasons of 2002 and 2003 to investigate the effect of water regime, nitrogen fertilizer levels and zinc application on maize yield and its water relations as well as some soil chemical properties.

A split- split-plot design with four replicates was used, the plot area was 42 m^2 (6 × 7m). Maize (*triple hybrid 320 V.*) was planted at the same site on 21 and 28 May in the first and second growing seasons, respectively.

Experimental treatments were conducted as follows:

- ♦ Water regime was located in the main plots.

I_1 : irrigation at 40% depletion of available soil moisture.
I_2 : irrigation at 55% depletion of available soil moisture.
I_3 : irrigation at 70% depletion of available soil moisture.
I_4 : irrigation at 85% depletion of available soil moisture.

- ♦ Nitrogen fertilizer levels were laid in sub plots.

N_1 : Addition of 90 kg N fed^{-1}.
N_2 : Addition of 110 kg N fed^{-1}.
N_3 : Addition of 130 kg N fed^{-1}.

- ♦ Zinc applications occupied the sub-sub-plots:

C :150 ppm of Zn-EDTA chelate was added as a foliar spray application.
M : 10 kg/fed Zn sulfate was added to the soil.
W : Without zinc applied (control).

Nitrogen fertilizer, in the form of ammonium nitrate (33.5 %N), was applied in two equal doses with the second and third irrigation. Zinc sulfate and zinc chelate were applied two times, i.e. 30 days after planting and 15 days later.

The soil of the experimental field was clayey in texture, non-saline non-alkaline soil. Some physical and chemical properties of the experimental field before planting were determined according to Black (1965), Garcia (1978) and Lindsay and Norvell (1978) as shown in Table 1.

Table 1: Mean values of some physical and chemical properties of the experimental field.

Particle size distribution, %			Total carbonate, %	O.M. %	Soil pH 1:2.5	EC dSm^{-1}	SAR	Bulk density gm/cm^3	Soil moisture characters, %		
Sand	Silt	Clay							F.C.	W.P.	A.S.W
23.2	33.0	43.8	2.10	1.48	8.10	3.4	7.60	1.30	42.8	21.0	21.8

Available macro and micro nutrients (ppm)						
N	P	K	Zn	Fe	Mn	Cu
18.2	6.8	256	0.78	16.3	13.4	0.92

F.C. : Field capacity W.P. wilting point A.S.W.: available soil water

Parameters studied:

1- Maize yield and its components: grain yield, 100-grain weight, straw yield and ear weight were determined at harvest time.

2- Water relations:

2.1- Amount of irrigation water applied (m^3 fed^{-1}.) was measured by cutthroat flume (20 × 90 cm) according to Mahrous (1971).

2.2. Water consumptive use (WCU) was determined for different soil depth (0-60 cm) in each plot as m^3 according to Israelsen and Hansen (1962).

2.2- Crop water use efficiency (CWUE) was calculated in kg/m^3 as follows:

$$CWUE = \frac{\text{yield (kg/fed.)}}{\text{water consumptive use } (m^3/\text{fed.})}$$

3- Soil chemical properties were determined in soil paste extract before and after harvesting according to Black (1965).
Statistical analysis was done according to Cochran and Cox (1960).

RESULTS AND DISCUSSION

Effect of different treatments on
1- Maize yield and its components:

Data in Table 2 indicated that the maize grain yield and its components were highly significantly affected by water regime during both seasons. Also, the data indicate that, the irrigation at 55% depletion of available soil moisture (I_2) produced the highest grain yield, 100-grain weight, straw yield and ear weight of maize (3525.6 kg/fed., 44.07 gm, 9.38 ton/fed. and 320.82 gm, respectively) in the first season and (3454.2 kg/fed., 42.86 gm, 9.67 ton/fed. and 336.85 gm, respectively) in the second season. These results may be due to good moisture and aeration condition in the root zone as well as high efficiency of nitrogen fertilization. These results could be confirmed by the data were obtained by Ragab *et al.* (1986); El-Refai *et al.* (1988); Sadik *et al.* (1995); Ghazy (2002) and Ragab, *et al.* (2002). On the other hand, the irrigation at 85% depletion of available scil moisture (I_4) gave the lowest values of maize grain yield and its components in both seasons. These results may be attributed to the low moisture content of soil and the low efficiency of nitrogen fertilization especially, during the flowering period (El-Kassaby *et al.*, 1985).

With regard to nitrogen fertilization, the data in Table 2 show that increasing nitrogen level from 90 to 130 kg N/fed. highly significantly increased grain and straw yields, 100-grain weight and ear weight of maize in both seasons. This increase may reflect the high response of maize plants to nitrogenous fertilizer and consequently improvement of plant growth parameters. This trend may be supported by findings of Sadik *et al.* (1995); Youns *et al.* (1995); El-Far (1996); Badawi and El-Moursy (1997); El-Hamdi *et al.* (1998); EL-Moursy *et al.* (1998) and Ragab (1998).

Also, the data in Table 2 reveal that the grain and straw yield, 100-grain weight and ear weight of maize in both seasons were high significantly increased with zinc application. The foliar addition of 150 ppm Zn-EDTA chelate was the best treatment, since it recorded the highest values of maize yield and yield components in the two growing seasons. This increase may be due to the improvement of the biochemical and physical conditions for maize plants through achieving the nutritional balance of those micronutrients with the applied nitrogen. These results may be enhanced by those obtained by Srinivasan (1992); El-Khateeb and Selim (1993); Abd El-Salam *et al.* (1994) and Ragab (1998).

The dada in Table 2 indicate again that the interaction between water regime and nitrogen fertilization levels (I × N) or zinc application (I × Z) had highly significant effects on maize yield and its components, except grain yield with (I × N) in the 2nd season. On the other hand, the interaction between nitrogen fertilizer and zinc application (N × Z) had highly significant effects on maize yield and its components in both seasons, except grain yield and ear weight in the 1st season and straw yield in the 2nd season.

The interaction between 1 × N × Z had highly significant effect on 100-grain weight and straw yield in the 1st season and 100-grain weight and ear weight in the 2nd season.

Table 2: Yield and yield components of maize crop as affected by different treatments (1st and 2nd seasons)

Treatments	1st season, 2002				2nd season 2003			
	Grain yield kg/fed.	100-grain weight (gm)	Straw yield ton/fed.	Ear weight (gm)	Grain yield kg/fed.	100-grain weight (gm)	Straw yield ton/fed.	Ear weight (gm)
Irrigation (depletion of available water,%)								
I_1 (40%)	3445.8	43.050	9.165	313.558	3391.57	41.936	9.497	329.236
I_2 (55%)	3525.6	44.067	9.376	320.822	3454.15	42.864	9.699	336.849
I_3 (70%)	3218.9	40.210	8.562	301.332	3127.42	39.166	8.855	307.539
I_4(85%)	2981.4	36.814	7.835	267.923	2842.37	35.843	8.112	281.321
F test	**	**	**	**	**	**	**	**
L.S.D. 0.05	49.945	0.317	0.073	13.803	70.15	0.323	0.145	2.745
0.01	71.763	0.456	0.105	19.832	100.79	0.464	0.208	3.944
Nitrogen (kg fed^{-1})								
N_1 (90)	3261.9	40.395	8.604	294.405	3169.35	39.261	8.892	309.123
N_2(110	3270.2	40.899	8.698	297.610	3184.53	39.813	9.011	312.482
N_3 (130)	3346.7	41.811	8.901	310.712	3257.75	40.783	9.220	319.603
F test	**	**	**	*	*	**	**	**
L.S.D. 0.05	35.985	0.191	0.044	10.972	68.93	0.176	0.083	1.640
0.01	48.765	0.259	0.60	-	-	0.239	0.112	2.223
Zinc (Zn)								
C (foliar spray)	3435.0	42.842	9.120	312.011	3351.90	41.693	9.462	327.613
M (Soil application)	3336.3	41.454	8.818	301.733	3221.86	40.364	9.140	316.821
W(without)	3107.5	38.809	8.265	288.982	3037.86	37.801	8.520	296.775
F test	**	**	**	**	**	**	**	**
L.S.D. 0.05	39.05	0.190	0.042	35.495	46.74	0.208	0.075	1.545
0.01	51.898	0.252	0.055	47.173	62.12	0.277	0.998	2.053
I × N	**	**	**	*	ns	**	*	**
I × Z	**	**	**	*	*	**	**	**
N × Z	ns	**	**	ns	*	**	ns	**
I × N × Z	ns	**	**	ns	ns	**	ns	**

1. Water relations:

1.1- amount of irrigation water applied:

The data in Table 3 reveal that the highest amount of irrigation water applied was obtained by I_1 treatment in the first and second seasons (3145 and 3105 m^3/fed., respectively). On the other hand, the lowest values (2255 and 2225 m^3/fed.) were recorded by I_4 treatment in the first and second seasons, respectively. These results may be due to that the irrigation at I_1 treatment received high amount and number of irrigation more than any other treatments. this trend could be confirmed by those recorded by Ghazy (2002) and Ragab *et al.* (2002).

1.2- Water consumptive use (WCU):

Data in Table 3 indicated that, I_1 treatment consumed water more than the other treatments, since it recorded the highest mean values of water consumptive use (2820 and 2800 m^3/fed.) in the 1st and 2nd seasons, respectively. While the lowest values of WCU (1885 and 1905 m^3/fed.) in the 1st and 2nd seasons, respectively were obtained by I_4 treatment. This trend may be explained on the basis that increasing the amount of irrigation water, is accompanied by increasing the water consumptive use. These results in general could be supported by those reported by Ragab *et al.* (1986); El-Refai *et al.* (1988); Sadik *et al.* (1995); Ghazy (2002) and Ragab *et al.* (2002).

1.3- Crop water use efficiency (CWUE):

The irrigation at 85% depletion of available soil moisture (I_4 treatment) gave the highest values of CWUE (1.58 and 1.49 kg/m^3) in the first and second seasons, respectively as shown in Table 3. While I_1 treatment gave the lowest values of CWUE in both seasons. These results may be due to that I_1 treatment consumed more amount of irrigation water than the other treatments. The obtained results are similar observation was found by Sadik *et al.* (1995); Ghazy (2002) and Ragab *et al.* (2002).

Table 3: Effect of irrigation water regime on amount of irrigation water applied, water consumptive use and crop water use efficiency in the 1st and 2nd seasons.

Season	Amount of irrigation water applied (m^3/fed.					Water consumptive use (m^3/fed.)					Crop water use efficiency (kg/m^3)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
1st season	3145	2885	2465	2255	2687.5	2820	2520	2175	1885	2350	1.22	1.40	1.48	1.58	1.42
2nd season	3105	2855	2495	2225	2670.0	2800	2550	2195	1905	2362.5	1.21	1.35	1.42	1.49	1.37
Mean	3125	2870	2480	2240	2678.75	2810	2535	2185	1895	2356.25	1.22	1.38	1.46	1.54	1.40

2- Soil chemical properties:

The rate of change of soil chemical properties after termination of the experiment in first and second seasons is presented in Table 4. The data reveal that increasing the amount of irrigation water applied led to a reduction in soil salinity (ECe), soluble ions (cations and anions) and sodium adsorption ratio (SARe) of the soil. It can be observed that the best treatment was I_1 treatment, since it recorded the highest reduction in ECe in the soil after the 1st and 2nd seasons (-1.68 and –1.85 dSm^{-1}, respectively) followed by I_2 treatment. On the other hand, decreasing the amount of irrigation water applied (I_4) led to accumulation of salts and has increased ECe in both seasons (0.80 and 1.15 dSm^{-1}, respectively).

Soluble ions were also affected by different irrigation treatments in both seasons. The data show that most of soluble ions were removed from the soil layers especially, Na^+, Cl^- and $SO_4^=$ ions. The irrigation at 40% depletion of available soil moisture (I_1) resulted in the highest reduction of soluble ions, followed by I_2. While the treatment I_4 (i.e., irrigation at 85% depletion of available soil moisture) led to increase the soluble salts of soil profile.

Table 4: Mean values of the changes occurred in some soil chemical properties after the 1st and 2nd seasons.

Irr. Treat.	EC dSm^{-1} at 25C	Cations meq/L				Anions meq/L				SAR
		Na^{+}	K^{+}	Ca^{++}	Mg^{++}	$Co_3^{=}$	HCO^{-}	Cl^{-}	$SO_4^{=}$	
Before experiments										
	3.4	20.8	0.4	7.8	7.3	0.0	5.8	17.1	13.4	7.60
the change after 1st season										
I_1	-1.68	-8.10	-0.08	-4.2	-1.9	0.0	0.25	-7.20	-6.0	-0.7
I_2	-1.45	-2.3	-0.01	-2.6	-0.8	0.0	0.10	-3.10	-2.5	-0.20
I_3	0.35	1.2	0.04	1.10	0.30	0.0	0.0	1.05	0.85	0.35
I_4	0.80	2.3	0.11	0.8	1.10	0.0	-0.20	2.4	1.10	0.60
The change after 2nd season										
I_1	-1.85	-9.5	-0.10	-4.8	-2.0	0.0	0.35	-7.9	-6.6	-0.92
I_2	-1.30	-2.7	-0.02	-2.9	-0.9	0.0	0.10	-3.4	-2.7	-0.22
I_3	0.48	1.9	0.05	1.20	0.40	0.0	0.05	1.10	0.90	0.41
I_4	1.15	2.8	0.12	0.8	1.30	0.0	-0.25	2.7	1.15	0.84

Also, the data in Table 4 indicat that, the higher amount of irrigation water applied, the lower the values of SAR. The reduction of SAR value of soil in the 1st and 2nd seasons (-0.78 and –0.92, respectively) was obtained by I_1 treatment followed by I_2 treatment. On the other hand, I_4 treatment led to increase SAR values in the 1st and 2nd seasons (0.6 and 0.84, respectively). These results may be due to the effect of higher amount of irrigation water applied enhanced the leaching of sodium salts from the soil profile. Similar trend was found by Ghazy (2002).

Generally, it could be concluded that, increasing nitrogen fertilization levels up to 130 kg N/fed. and irrigation at 55% depletion of available soil moisture with foliar application of 150 ppm zinc is the optimum interaction, since it led to the highest values of yield and yield components of maize (*Triple hybrid 320 V.*)

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تأثير ترشيد مياه الرى و مستوى التسميد الأزوتى و أضافة الزنك على المحصول و العلاقات المائية للذرة الشاميه

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أقيمت تجربه حقليه بمزرعة محطة البحوث الزراعية بسخا خلال موسمين متتابعين (صيف ٢٠٠٢ ، ٢٠٠٣م) لدراسة تأثير إضافة مستويات مختلفة من التسميد الأزوتى و ترشيد مياه الرى مع إضافة الزنك على المحصول و العلاقات المائية للذرة الشاميه و أيضا بعض الخواص الكيميائية للتربة.

تم تنفيذ التجربه بالتصميم الاحصائى لقطع المنشقة مرتين فى اربع مكررات. المعاملات الرئيسية هى أربعة مستويات استنفاد الرطوبه الارضية (٤٠%، ٥٥%، ٧٠%، ٨٥% من الرطوبه الأرضية الميسرة)، بينما تم توزيع ثلاثة معدلات من النتروجين (٩٠، ١١٠، ١٣٠ كجم ازوت/فدان) فى القطع المنشقة الأولى، أما فى القطع المنشقة الثانيةفقد تم إضافة ثلاث معاملات من الزنك (١٥٠ جزء/مليون رشا – ١٠ كجم /فدان سلفات زنك أرضى – بدون زنك) .

يمكن تلخيص أهم النتائج كما يلى:

- وجد تأثير معنوى لترشيد مياه الرى على محصول الذرة الشاميه و مكوناته خلال موسمى الدراسة. و أن رى الذرة عند استنفاذ ٥٥% من الرطوبة الأرضية الميسرة أعطى أعلى إنتاجية للمحصول و مكوناته. فى حين أن الرى عند استنفاذ ٨٥% من الرطوبة الأرضية الميسرة أعطى أقل إنتاجية للمحصول.