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RESPONSE OF MAIZE CROP TO IRRIGATION UNDER DIFFERENT RATES AND DOSES OF NITROGEN FERTILIZATION IN THE NORTH NILE DELTA REGION

Aiad, M. A.; E. A. Moursi; R. A. El-Dissoky and M. M. Amer
Soils, Water and Environment Res. Inst, Agric. Res. Center, Giza, Egypt.

ABSTRACT

Two field trials were carried out at the Experimental Farm, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate during the two successive summer growing seasons of 2012 and 2013. The research aimed to study the effect of irrigation at different soil moisture depletion (I_1: at 45%, I_2: at 60% and I_3: at 75% depletion of available soil moisture, respectively), nitrogen rates (N_1: 60, N_2: 90 and N_3: 120 kg N fed^{-1}) and doses number of nitrogen application (D_1: one dose, D_2: two equal doses and D_3: three equal doses) on maize yield and its components, nitrogen uptake by plants, N-use efficiency and some water relations. The experimental design was split split plot with three replicates, the main plots were for irrigation treatments, where the sub plots were for N-rates and the sub-sub plots were for doses number of N application.

The main results can be summarized as follows:

- Irrigation at 75 % depletion of available soil moisture (I_3) decreased seasonal water applied, water consumptive use and water stored in the effective root zone by 18.08, 16.78, and 17.02%, respectively compared with irrigation at 45% depletion. Also, the highest means of water productivity (WP) and productivity of irrigation water (PIW) were 1.95 and 1.24 kg/m^3, respectively with irrigation at 60 % depletion (I_2).
- Irrigation at 60% depletion (I_2) recorded the highest mean of water application efficiency (89.60%), whereas the irrigation orders was I_2> I_3>I_1.
- Irrigation at 45% depletion (I_1) recorded the highest mean for grain yield (3.363 ton fed^{-1}), stalks yield (9.313 ton fed^{-1}), weight of 100 grains (43.899g) and ear weight (316.119g).
- Application of N-rate N_3 recorded the highest means of grain yield (3.507 ton fed^{-1}), straw yield (9.56 ton fed^{-1}), weight of 100 grains (43.176g) and ear weight (310.948g), respectively.
- Application of N-rate at three doses (D_3), recorded the highest means of grain yield (3.585 ton fed^{-1}), straw yield (9.216 ton fed^{-1}), weight of 100 grains (43.466g) and ear weight (315.202g).
- Irrigation at 45% depletion (I_1) recorded the highest mean of N-uptake for grains and stalks.
- Application of nitrogen rates increased N-uptake for maize grains and stalks up to N_3.
- Increased the doses number of N application increased N-uptake for maize grains and stalks up to D3 (three equal doses).
- The values of NUE increased by 15.65% with splitting N-rate into three doses compared with application at one dose, but decreased with increasing application N-rate and irrigation at 75 % depletion.
- Most of interactions among irrigation, nitrogen rates and doses number of N application showed significant effect on grain yield and its components and N-uptake in both maize grains and stalks, and positive effect on N-use efficiency

Keywords: irrigation, nitrogen rates and doses number, maize yield, water relations, and nitrogen use efficiency.

INTRODUCTION

Maize (*Zea mays L.*) is considered as one of the most important cereal crops in Egypt for its wide use in human and livestock feeding and industrial aspects. It ranks the second crop after wheat, where it grows in the summer season. Total annual area cultivated with maize varieties was estimated 1.5-2.0 million feddans. Total national production of maize is about 5.43 million tons, while the demand is for at least 7 million tons (El-Atawy and Eid, 2010). This reflects the size of the problem and efforts that needed to increase maize production. This can be achieved by breeding high yielding varieties, through application of improved agro-techniques, using a proper irrigation regime and fertilization management.

In Egypt, water was and still the most critical and limited factor in crop production. The Egyptian water budget from the Nile River is 55.5 milliard cubic meter. Under limitation of fresh water resources the farmers will have to use other resources in irrigation, and we should do our best towards effective rationalization of irrigation on the farm level. So, effective water management at irrigation sector is the principal way towards the rationalization policy for the country in this aspect, effective on farm irrigation management becomes a must. Therefore, the knowledge of the amount of water required to produce the highest economical grain yield of maize is essential. Also, planning for irrigation of maize becomes necessary to know about the quantity of water consumed in growing this crop and the efficiency of the applied water. So, the suitable irrigation water regime and nutritional program are the main effective tools for increasing yield and improving its quality. Irrigation with ratios from available soil moisture becomes a must to use in order to make rationalization for irrigation water. Tremendous efforts should be implemented towards the aim of such effective water management on the farm level. Some of these efforts include irrigation according to depletion of available soil moisture from the effective root zone and supplying water according to plant requirements to make water rationalization for maize irrigation.

Corn cultivation requires large quantities of water seasonally to obtain a large crop. Ayotamuno *et al.*, (2007) reported that the maximum plant height and the other maize yield components increased with increasing irrigation water. Abdel-Hafez *et al.*, (2008) reported that the highest value of grain yield was obtained with irrigation at 1.3 ETc (evapotranspiration) as compared to 1 and 0.7 ETc. Ko and Piccini (2009) in Texas, stated that irrigation management of corn at 75% Etc is feasible with 10% reduction in grain yield and increased water use efficiency.

Nitrogen is considered one of the major nutrients required by the plants for growth, development and yield. Maize is one of crops that need high nitrogen fertilization, Nofal, *et al.*,(2005) found that plant growth parameters, grain yield, 1000-grain weight and NPK contents of maize were gradually increased with increasing nitrogen fertilization levels up to 160 kg

N/fed. Abo El-Atta (2006) found that increasing N fertilization levels had a positive effect on field water use efficiency, grain and stalk yields, also N concentrations in grain and stalk. Wajid *et al.*, (2007) reported that the increase in nitrogen application resulted in maximum stem length, 100-grain weight and grain yield of maize. Also, splitting application of N may help growers make better decision on N application (Feinerman *et al*., 1990). Yield may *increase with using split application method when using irrigation (Randall et* al., 2003 and Gehl et al., 2005), whereas Randall et al., (2003) showed that the lowest grain yield was achieved by full N application versus the highest grain yield with split N fertilization. Khan *et a*l., (2006) reported that the fertilizer application with three split doses results in highest agronomic efficiency as compared to no split and two splits. El-Agrodi et al., (2011) found that application of 120 kg N/fed in four doses as 40, 20, 20 and 20% added after 14, 24, 48 and 56 days after sowing recorded higher values of 100-grain weight, maize stalk and grain yield of maize.

The main objectives of the present study were to investigate the suitable irrigation water regime for maize in the studied region, and the effect of nitrogen application at different rates and splitting doses on maize yield and its components, N-uptake and N use efficiency.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate (The site is located at $31^{o}07$ N latitude and $30^{o}57$ E Longitude with an elevation of about 6 meters above mean sea level), during the two successive summer growing seasons of 2012 and 2013. The work aimed to study the effects of irrigation at different soil moisture depletion, nitrogen rates and doses number of N application on maize yield and its components, nitrogen uptake by plants, nitrogen use efficiency and some water relations in the North Nile Delta region.

The experiments were designed as split-split plot with three replicates. The main plots were assigned for the irrigation treatments (irrigation at different depletion of available soil moisture, I_1: Irrigation at 45% depletion, I_2: Irrigation at 60% depletion and I_3: Irrigation at 75% depletion). The sub plots were for nitrogen rates (N_1:60 kg, N_2:90 kg and N_3: 120 kg N/fed). The sub sub plots were devoted for the doses number of nitrogen application (D_1: one dose, D_2: two equal doses and D_3: three equal doses).

Soil samples at different depths from the experimental site were collected each 20 cm depth up to 60 cm and analyzed for some chemical and physical characteristics according to Jackson, (1973) and Klute, (1986) and were presented in Tables 1 & 2. Also, some meteorological data at Sakha Station during the two studied seasons was daily recorded and their monthly mean values were presented in Table 3.

Table 1: Some chemical characteristics for the studied soil at different depths (Average of the two growing seasons).

Soil depth (cm)	*pH	**EC dSm^{-1}	Soluble cations ($Meq\ L^{-1}$)				Soluble anions ($Meq\ L^{-1}$)				Available NPK (ppm)		
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	N	P	K
0-20	7.85	3.48	5.6	7.7	23.7	0.3	0.0	3.5	16.6	17.2	42.6	9.9	333
20-40	7.96	3.70	5.9	8.1	25.2	0.3	0.0	4.0	17.6	17.9			
40-60	8.11	3.89	6.2	8.6	26.5	0.5	0.0	4.5	18.5	18.7			
Mean	7.97	3.69	5.9	8.13	25.13	0.37	0.0	4.0	17.9	17.9			

* pH soil water suspension 1:2.5
**EC were measured in the extract of soil paste at 25^{o}C.

Table 2: Some physical characteristics and soil water constants for the studied soil at different depths (Average of the two growing seasons).

Soil depth (cm)	Particle size distribution			Texture class	Some soil water constants			Bulk Density ($kg\ m^{-3}$)
	Sand%	Silt %	Clay %		Field Capacity (FC) %	Permanent Wilting Point %	Available Water %	
0-20	25.00	30.10	44.90	Clayey	43.50	22.85	20.65	1.22
20-40	24.10	30.80	45.10	Clayey	39.40	21.30	18.10	1.34
40-60	24.90	29.70	44.40	Clayey	37.60	20.80	16.80	1.41
Mean	24.80	30.20	45.00	Clayey	40.13	21.65	18.48	1.32

Table 3: Meteorological data at Sakha Agricultural Research Station during the two growing seasons

Months	Temp. ^{o}C			Relative humidity %	Wind speed km/day	Evaporation, cm/day
	Max.	Min.	Mean			
First growing season 2012						
May	30.82	20.78	25.80	62.88	100.12	0.572
June	32.98	23.51	28.25	65.19	103.96	0.649
July	33.16	25.30	29.23	68.54	91.74	0.605
August	34.65	25.02	29.84	68.52	90.91	0.579
September	32.28	22.73	27.51	67.59	86.33	0.660
October	29.92	20.64	25.28	70.28	74.15	0.430
November	25.32	15.46	20.39	75.50	56.97	0.187
December	21.38	10.57	15.98	72.75	62.98	0.227
Second growing season 2013						
May	31.43	21.81	26.62	60.41	45.78	0.613
June	32.44	23.97	28.21	62.95	115.37	0.661
July	32.32	24.31	28.32	67.14	110.99	0.611
August	33.79	24.76	29.28	72.10	90.24	0.513
September	32.50	22.93	27.72	68.80	87.60	0.382
October	30.40	20.80	25.60	70.91	72.50	0.300
November	25.90	15.92	20.91	75.20	58.10	0.234
December	21.50	10.75	16.12	72.50	63.45	0.154

Maize (single hybrid 10) was planted on 15th and 20th May and harvested on 23rd and 30th September in the first and second growing seasons 2012 and 2013, respectively. All cultural practices for the crop were the same as recommended for the studied area except the studied parameters (irrigation treatments, nitrogen rates and doses). Nitrogen fertilizer was applied as urea (46.5%N) in one dose with 1st irrigation after sowing, or in two equal doses with 1st and 2nd irrigation after sowing, and in three equal doses with sowing irrigation, 1st and 2nd irrigation after sowing. The plot area was 180 m^2 (30 m in length and 6 m in width).

Maize yield and its components: Grain yield (ton fed^{-1}),weight of 100 grains (g), stalk yield (ton fed^{-1}) and ear weight (g) were recorded after harvest.
N-uptake in both maize grains and stalks were calculated by nitrogen concentration that determined according to Page (1982).

Nitrogen fertilization efficiency: was calculated as N utilization efficiency NU_tE and N use efficiency (NUE) as follows:

1. N utilization efficiency NU_tE (Fiez *et al.,* 1995) is equal to grain yield per unit of total N uptake.
   NU_tE (kg/kg N-uptake) = grain yield (kg fed^{-1}) / total N-uptake (kg fed^{-1}).
2. N use efficiency (NUE) (Barbar, 1976) was calculated as follows:
   NUE (kg/kg N-applied) = grain yield (kg fed^{-1}) / total N applied (kg fed^{-1})

Water Relations:

1. Amount of irrigation water applied (m^3 fed^{-1}) for each irrigation treatment was measured and then seasonal water applied was recorded by using cut-throat flume (30*90 cm) through the whole growing season and calculated as m^3 fed^{-1} according to Early (1975).
2. Water consumptive use (m^3 fed^{-1}) by growing plants was calculated based on soil moisture depletion (SMD) according to Hansen *et al.*, (1979).

$$Cu = SMD = \sum_{i=1}^{i=n} \frac{\theta_2 - \theta_1}{100} * Dbi * Di * 4200$$

Where: Cu=Water consumptive use in the effective root zone(60cm),

θ_2 = Gravimetric soil moisture percentage after irrigation,

θ_1 = Gravimetric soil moisture percentage before the next irrigation,

Dbi = Soil bulk density (kg/m^3) for depth,

Di = Soil layer depth (20 cm) and

1 = Number of soil layers (1-3).

3. Water efficiencies % (WAE) were calculated according to Israelsen and Hansen (1962) as follows.

$$WAE = \frac{\text{Total water stored in the effective root zone}}{\text{Total water applied}} * 100$$

4. Water productivity (WP) is generally defined as crop yield per cubic meter of water consumption. Concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. It was calculated according to Ali *et al.,* (2007)

$$WP = GY/ET$$

Where: WP = Water productivity (kg seeds/m^3 WCU)
GY = Grain yield kg fed^{-1}
ET = Total water consumption of the growing season (m^3 fed^{-1})

5. Productivity of irrigation water (PIW) was calculated according to Ali *et al.* (2007) as kg grains/m^3 water applied.

$$PIW = Gy/I$$

Gy = Grain yield (kg fed^{-1})
I = Irrigation water applied m^3 fed^{-1}

All data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatments were compared by the least significant difference (LSD) at 5% level of significance which developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Water Relations:

1- Amount of seasonal water applied:

Data presented in Table 4 show that the mean values of seasonal water applied during the two growing seasons were decreased by 11.64 and 17.63% with irrigation at 60 and 75% depletion of available soil moisture, respectively. Whereas the highest average of seasonal water applied (3049.2 m^3 fed^{-1}) was recorded with irrigation at 45% depletion (I_1). Increasing the amount of seasonal water applied under irrigation treatment I_1 comparing with other irrigation treatments I_2 and I_3 is due to the decrease in irrigation intervals between irrigations. So, increasing number of irrigations under the conditions of this treatment and hence, increasing amount of seasonal water applied. These results are in accordance with those reported by El-Atway and Eid (2010), Moursi *et al.*, (2011), Beshara (2012), Mohamed *et al.*, (2012) and Kassab (2012).

Table 4: Effect of irrigation treatments, nitrogen rates and doses number of N application on seasonal water applied of maize in the two growing seasons, 2012 and 2013.

Irrigation treatments	Seasonal water applied				Average of the two growing seasons	
	1st growing season		2nd growing season			
	m^3 fed^{-1}	cm fed^{-1}	m^3 fed^{-1}	cm fed^{-1}	m^3 fed^{-1}	cm fed^{-1}
I_1	3019.8	71.90	3078.6	73.30	3049.2	72.60
I_2	2625.0	62.50	2763.6	65.80	2694.3	64.15
I_3	2473.8	58.90	2549.4	60.70	2511.6	59.80

2- Water consumptive use (WCU) (m^3 fed^{-1}):

Data in Table 5 show that the mean values of water consumptive use were decreased with irrigation treatments I_2 and I_3 . The highest mean of WCU (1902.47 m^3 fed^{-1}) was recorded under irrigation treatment I_1. On the other hand the lowest mean value (1583.23 m^3 fed^{-1}) was recorded under irrigation treatment I_3. This effect of irrigation treatments on water consumptive use might be attributed to the increase in the amount of water applied. So, the values of water consumptive use increased under such conditions. Generally, seasonal water consumptive use decreased as soil available water amount decreased. These results are in agreement with those obtained by Ashoub *et al.*, (1996), Ibrahim *et al.*, (2005), Awad *et al.*, (2009), Moursi *et al.*, (2011) and Beshara (2012).

Tale 5: Effect of irrigation treatments on the water consumptive use, water productivity, productivity of irrigation water, water application efficiency and water storage in the effective root zone (Average of the two growing seasons).

Irrigation treatments	Water consumptive use (m^3 fed^{-1})	Water productivity (kg/m^3)	Productivity of irrigation water (kg/m^3)	Water application efficiency (%)	Water stored in the effective root zone (m^3 fed^{-1})
I_1	1902.47	1.77	1.10	85.81	2591.40
I_2	1706.25	1.95	1.24	89.60	2352.00
I_3	1583.23	1.93	1.22	86.93	2150.40

3- Water productivity (WP) and productivity of irrigation water (PIW) (kg/m^3):

Also, data in Table 5 show that irrigation at different soil moisture depletion effect on water productivity and productivity of irrigation water; whereas the means for WP and PIW were increased under irrigation treatments I_2 and I_3 compared with I_1. These increasing for WP and PIW might be due to the decrease in the amount of water consumptive use and water applied under the conditions of irrigation treatments I_2 and I_3. These results are in the same line with those obtained by Awad *et al.,* (2009), Moursi *et al.,* (2011) and Beshara (2012).

4- Water application efficiency (%):

Presented data in Table 5 show that the mean values of water application efficiency were affected by irrigation treatments. The highest percentage (89.60) was recorded under irrigation at 60% depletion of available soil moisture (I_2). Whereas, water application efficiency can be descended in order $I_2>I_3>I_1$.

5- Water stored in the effective root zone (m^3 fed^{-1})

Also, data in Table 5 reveal that the means of water stored in the effective root zone were decreased by 17.02% with irrigation at 75% depletion of available soil moisture. Increasing the amount of water stored in the effective root zone under irrigation treatment I_1 might be attributed to the increase in the number of irrigations and hence, increasing amount of water applied. So, large amounts of water still stored in this area that over plants requirements. These results are in a great harmony with those obtained by Beshara (2012).

Maize yield and its components:

1-Grain yield (ton fed^{-1}):

As found in Table 6, data show that the mean values of maize grain yield were affected by irrigation treatments, nitrogen rates and doses number of N application.

Concerning the effect of irrigation treatments, results reveal that maize grain yield were significantly decreased with irrigation at 75% depletion of available soil moisture, whereas irrigation at 45% depletion (I_1) recorded the highest mean of grain yield (3.363 ton fed^{-1} equal 24.02 ardab/fed). Increasing maize grain yield under irrigation treatment I_1 comparing with the others, I_2 and I_3 might be attributed to the increase in the number of watering under the conditions of this treatment (I_1), and consequently increasing the amount of water applied, and hence, increasing availability of water and nutrients. So, increasing amount of nutrients uptake, therefore, forming strong and healthy plants which give a high yield in comparison with the other irrigation treatments which always exposed to water stress so, plants suffer from obtaining their water and nutritional requirements leading in yield drop. These findings are in an agreement with those obtained by Elarquan and Abdel Kariem (1982) who indicated that both yield and yield components of corn grown under 20% soil moisture deficit treatment exceeded that of 50% and 80% of soil moisture deficit. Harder *et al.,* (1982) and El-Atway and Eid (2010) reported that grain yield of maize was reduced by 33% due to the severity and duration of soil moisture stress.

Regarding the effect of N-rates on maize grain yield, data in the same table show that grain yield were significantly increased by increasing N-rates up to N_3. Data reveal that N_2 and N_3 rates increased grain yield by 18.38 and 22.57%, respectively compared to N_1. This increasing in maize grain yield might be due to low in soil available N that reflected on responses of plants to application of N-rate. These results are in agreement with those obtained by Zhou *et al.*, (2011) and Beshara (2012).

Data in the Table 6 show also that maize grain yield were significantly affected by splitting nitrogen into three doses D_3 comparing with its application on two doses D_2 or one dose D_1. Splitting N rate at three doses (D_3) increased grain yield by 19.77% compared with D_1. This may be attributed to decreasing the fertilizer losses comparing with application in one or two doses. So, fertilization benefit for plants will increase, therefore, increasing grain yield. These results are in accordance with those reported by Randall *et al.,* (2003), Malakouti *et al.*, (2009), El-Atway and Eid (2010) and El-Agrodi *et al*., (2011).

Table 6: Effect of irrigation treatments, nitrogen rates and doses number of N application on maize yield and its components in means of the two growing seasons 2012 and 2013 (Average of the two growing seasons).

Treatments	Grain yield (ton fed^{-1})	Stalk yield (ton fed^{-1})	100-grain weight (g)	Ear weight (g)
Irrigation treatments				
I_1	3.363	9.313	43.899	316.119
I_2	3.334	8.832	41.892	301.617
I_3	3.058	8.649	40.770	294.142
LSD 0.05	0.021	0.063	0.657	10.774
Nitrogen rates				
N_1	2.861	8.701	41.266	299.928
N_2	3.387	8.937	42.119	301.002
N_3	3.507	9.156	43.176	310.948
LSD 0.05	0.016	0.043	0.548	6.990
Nitrogen doses				
D_1	2.993	8.560	40.599	290.120
D_2	3.282	9.018	42.496	306.056
D_3	3.585	9.216	43.466	315.702
LSD 0.05	0.015	0.042	0.466	6.669
The interactions				
I*N	**	**	*	ns
I*D	**	**	ns	ns
N*D	**	*	ns	ns
I*N*D	**	**	*	ns

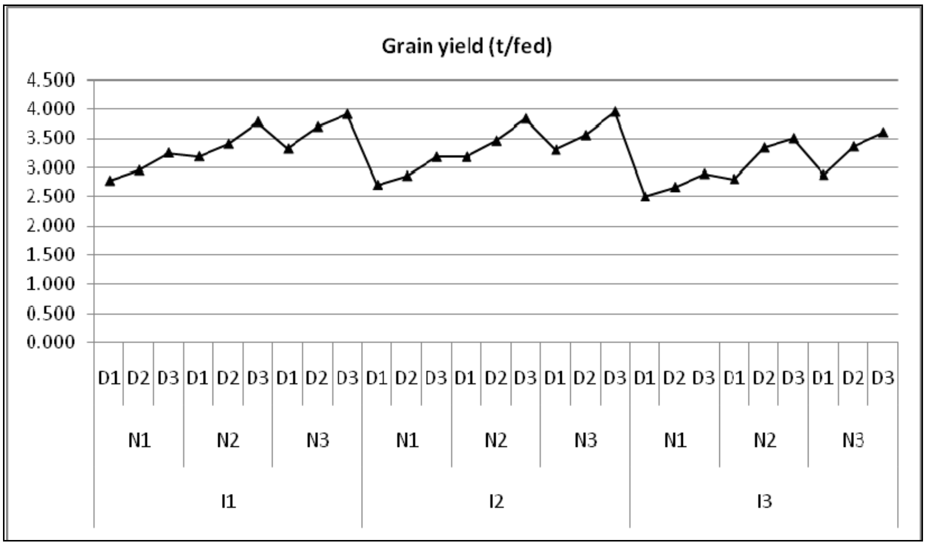

Fig. 1: interactions effect on grain yield (ton fed^{-1}) (Average of the two growing seasons 2012 and 2013).

Concerning interactions effect, results in Table 6 and Fig. 1 show that all interactions among irrigation treatments, N-rates and doses number of N application have significant effect on grain yield. It is obvious from Fig. 1 that interaction between N_3 rate and splitting D_3 was more effective on increasing grain yield. Whereas, the differences between interactions N_3*D_3 and N_2*D_3 were insignificant for grain yield. As for interaction I*N*D, Fig. 1 reveal that the differences between interactions I_1*N_3*D_3, I_2*N_3*D_3, I_1*N_2*D_3 and I_2*N_2*D_3 were insignificant. This effect may be due to splitting N application that decreased the loss of N, also decrease the amount of water applied that reflected on decreasing the loss of nutrients by leaching, and consequently on grain yield. These results are in accordance with that obtained by Abdel-Maksoud *et al*., (2002), Taha *et al.,* (2010) and El-Agrodi et al., (2011).

2- Stalks yield, weight of 100 grains and ear weight:

As shown in Table 6, data illustrate that the mean values of stalks yield, weight of 100 grain and ear weight were significantly affected by irrigation at different soil moisture depletion. Whereas the average values of stalks yield, weight of 100 grains and ear weight were decreased with irrigation at 60 and 75 % depletion of available soil moisture (I_2 and I_3) compared to irrigation at 45% depletion (I_1).

Concerning the effect of N-rates, the averages for stalks yield, weight of 100 grains and ear weight were significantly increased with application of N-rates up to level N_3 (120 kg N/fed). These results are in accordance with that obtained by Nofal, *et al.*, (2005), Abo El-Atta (2006) and Beshara (2012).

Also, splitting N-rate into number of doses significantly affect stalk yield, weight of 100 grain and ear weight. Whereas the highest means of stalk yield, weight of 100 grains and ear weight were recorded under application of nitrogen fertilizer in three doses (D_3). These results are in agreement with that obtained by Harder *et al.*, (1982), Khan *et al.,* (2006), El-Atway and Eid (2010), Moursi *et al.,* (2011) and Zhou *et al.,* (2011).

Regarding the effect of interactions, all interactions (I*N, I*D, N*D and I*N*D) have a significant effect on stalk yield. As for weight of 100-grain, results revealed that interactions I*N and I*N*D have a significant effect but the interactions I*D and N*D was insignificant. All interactions (I*N, I*D, N*D and I*N*D) have insignificant effect on ear weight.

N-uptake (kg fed^{-1}):

Presented data in Table 7 and Fig. 2 show the effect of irrigation treatments, N-rates and N-doses on N-uptake (kg fed^{-1}).

Concerning the effect of irrigation, data reveal that N-uptake by maize grain and stalk yield and total N-uptake were significantly affected by irrigation at different soil moisture depletion. Irrigation at 45% soil moisture depletion (I_1) recorded the highest N-uptake for maize grain, stalk and total. Generally, the mean values for N-uptake can be descended in the order $I_1>I_2>I_3$. This increasing of N-uptake under irrigation treatment (I_1) may be attributed to increasing number of irrigations and hence, increasing amount of irrigation water applied, which reflect on availability of soil nutrients, so increasing nitrogen uptake by different plant parts comparing with stressed plants under irrigation I_2 and I_3. These results are in the same line with those obtained by Varma (1976) and Beshara (2012).

Increasing N-rates significantly affected N-uptake by maize grain and stalks yield and total uptake. Results show that N_3 level (120 kg N/fed) recorded the highest means for N-uptake comparing with N_1 and N_2 rates. Generally, the mean values of N-uptake can be descended in order $N_3>N_2>N_1$. This effect may be return to high response of maize to N fertilization. These findings are in the same line with those obtained by Nofal, *et al.*, (2005), Abo El-Atta (2006) and Beshara (2012).

Concerning the effect of doses number of N application, results reveal that splitting N-rate into numbers of doses significantly affect N-uptake by maize grains and stalks. Application of N-rate into three doses (D_3) recorded the highest averages of N-uptake by maize grains and stalks and total uptake. This effect might be due to splitting nitrogen decreases nitrogen losses (through leaching and volatilization) and give big chance for plants to absorb N, that reflect on total N-uptake and strong plants with a good vegetative cover. Also, under the conditions of splitting nitrogen into doses give plants a good chance to take their nutritional requirements with an easy way. These results are in accordance with those obtained by Giuliani *et al.*, (2011) and Beshara (2012).

Table 7: Effect of irrigation treatments, nitrogen rates and doses number of N application on N-uptake (Average of the two growing seasons 2012 and 2013).

Treatments	N-uptake (kg fed^{-1})			NUtE (kg grain/kg N-uptake)	NUE (kg grain/kg N-applied)
	Grains	Stalks	Total-uptake		
Irrigation treatments					
I_1	52.717	60.124	112.841	29.989	42.527
I_2	49.513	57.757	107.270	31.334	39.096
I_3	43.309	51.354	94.662	32.493	35.909
LSD at 5%	0.021	0.063	0.657	--	--
Nitrogen rates					
N_1	40.138	50.081	90.219	31.902	47.685
N_2	50.762	57.332	108.093	31.568	39.595
N_3	54.639	61.822	116.461	30.346	30.252
LSD at 5%	0.016	0.043	0.548	--	--
Nitrogen doses					
D_1	42.108	49.346	91.454	32.807	36.822
D_2	48.994	57.236	106.230	31.086	37.235
D_3	56.440	64.746	121.186	29.716	40.727
LSD at 5%	0.015	0.042	0.466	--	--
The interactions					
I*N	**	**	**	--	--
I*D	**	**	**	--	--
N*D	**	**	**	--	--
I*N*D	**	**	**	--	--

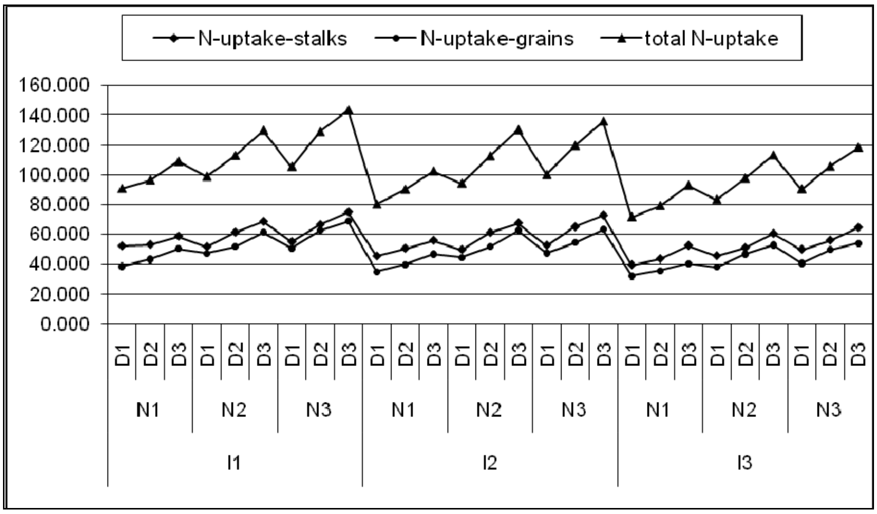

Fig. 2: Interactions effect among irrigation, N-rates and doses number of N application on N-uptake in maize grains and stalks (Average of the two growing seasons).

Data in Table 7 and Fig. 2 show also that all interactions among irrigation, N-rates and N-doses (I*N, I*D, N*D and I*N*D) significantly affect N-uptake in both maize grain and stalks yield. The highest averages of total N-uptake were recorded under interaction I*N*D and can be order as follows: $I_1*N_3*D_3 > I_2*N_3*D_3 > I_1*N_2*D_3 > I_2*N_2*D_3$. These results are accordance with that obtained by Abdel-Maksoud et al., (2002) and Taha *et al.,* (2010).

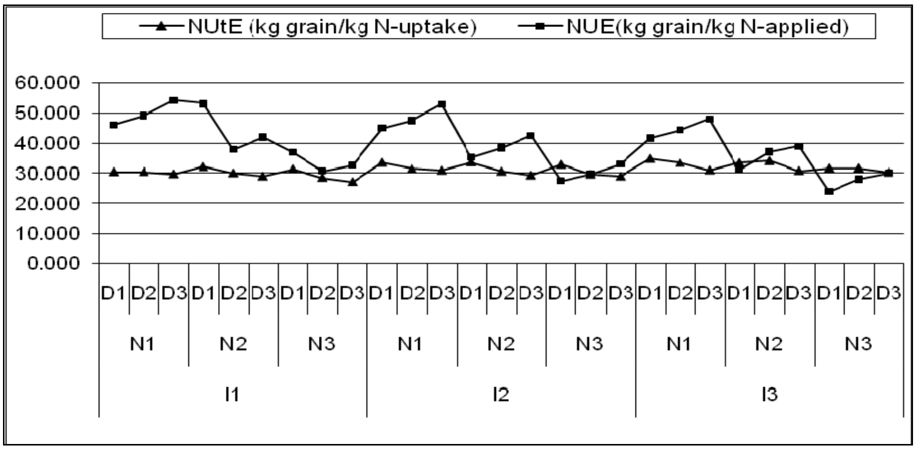

Fig. 3: Interactions effect among irrigation, N-rates and doses number of N application on NUtE and NUE of the average of two seasons 2012 and 2013.

N Fertilization Efficiency:

Data in Table 7 and Fig. 3 illustrate the effect of irrigation treatments, N-rates and N-doses on nitrogen utilization efficiency (NUtE) and nitrogen use efficiency (NUE).

Results reveal that irrigation at different soil moisture depletion affected NUtE (kg grain/kg N-uptake) and NUE (kg grain/kg N-applied). Whereas there were slight differences between averages of NUtE or between averages of NUE. Irrigation at 60% depletion of available soil moisture (I_2) was moderately for NUtE and NUE.

Data reveal also that increasing N–rates affected on N fertilization efficiency, whereas the mean values of NUtE and NUE were decreased with raising N-rates. While application of N_2 rate gave moderate values of NUtE and NUE.

Splitting nitrogen fertilizer levels into two and three doses affected NUtE and NUE, where the value of NUE was increased by 15.65% with splitting N-rate into three doses (D_3) compared with application in one dose (D_1).

Regarding the effect of interactions, results in Fig. 3 reveal that all interactions (I*N, I*D, N*D and I*N*D) affect NUtE and NUE. As for NUtE, results reveal that interactions among I_2, N_2, N_3 and D_3 were more effective. As for NUE, the interactions among I_1, N_2, N_3 and D_3 and interactions among I_2, N_2, N_3 and D_3 were more effective.

Conclusion

Finally, from the previous results it could be concluded that irrigation at 60% depletion of available soil moisture saved amount of seasonal water applied by 11.64% (355 m^3 fed^{-1}), and achieved the highest water application efficiency (89.60%). In addition, splitting N fertilizer at rates 90 and 120 kg fed^{-1} into three doses were more effective in increasing grain and stalks yield, N-uptake and N fertilization efficiency. So this study can recommend that irrigation maize crop at 60% depletion of available soil moisture with splitting N fertilization at 90 kg N fed^{-1} into three equal doses under the same conditions of study is the best for yield and quality of maize.

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استجابة محصول الذر ة الشامية للري تحت معدلات ودفعات الإضافة المختلفة للتسميد النيتروجينى بمنطقة شمال دلتا النيل

محمود أبوالفتوح محمود عياد ، السيد أبوالفتوح مرسى ، رمضان عوض الدسوقى و مجاهد محمد عامر
معهد بحوث الأراضي والمياه والبيئة - مركز البحوث الزراعية - الجيزة - مصر.

أجريت تجربتان حقليتان فى المزرعة البحثية بمحطة البحوث الزراعية بسخا محافظة كفرالشيخ وذلك خلال موسمين نمو صيفين متتاليين ٢٠١٢ و ٢٠١٣، لدراسة تأثير الرى عند استنفاذ درجات مختلفة من الرطوبة الأرضية الميسرة (عند استنفاذ ٤٥، ٦٠ و٧٥%)، معدلات السماد النتروجينى (٦٠،٩٠ و١٢٠ كجم ن/فدان) وعدد دفعات إضافة السماد النيتروجينى (جرعة واحدة ، جرعتين متساويتين وثلاث جرعات متساوية) على محصول الذرة الشامية ومكوناته وتركيز والممتص من النيتروجين بواسطة النباتات وكفاءة استخدام النيتروجين وبعض العلاقات المائية. صممت التجارب كقطع منشقة مرتين فى ثلاث مكررات خلال موسمي الدراسة حيث كانت المعاملات الرئيسية معاملات الرى والمعاملات الشقية الأولى هى معدلات السماد النيتروجينى والمعاملات الشقية الثانية هي عدد دفعات إضافة السماد النيتروجينى.

ويمكن تلخيص النتائج المتحصل عليها فيما يلى:

- أدى الرى بعد استنفاذ ٧٥% من الماء الميسر إلي نقص كلا من المياه الموسمية المضافة ، الاستهلاك المائي والماء المخزن فى منطقة الجذور الفعالة ب ١٨.٠٨و ١٦.٧٨ و١٧.٠٢ % على التوالى مقارنة بالرى بعد استنفاذ ٤٥% من الماء الميسر. وكذلك سجلت معاملة الرى بعد استنفاذ ٦٠% من الماء الميسر أعلى المتوسطات للكفاءة الإنتاجية للمياه المستهلكة (١.٩٥كجم/م^3) والمياه المضافة (١.٢٤كجم/م^3).
- سجلت معاملة الرى بعد استنفاذ ٦٠% من الماء الميسر أعلى متوسط من كفاءة إضافة مياه الرى (٨٩.٦٠ %)، حيث كان ترتيب الرى كمايلى: الرى بعد استنفاذ ٦٠% > الرى بعد ٧٥% > الرى عند ٤٥%.
- سجلت معاملة الرى بعد استنفاذ ٤٥% من الماء الميسر أعلى المتوسطات لكل من محصول الحبوب (٣.٣٦٣ طن/فدان) ومحصول الحطب (٩.٥٦٠طن/فدان)، ووزن ١٠٠ حبة (٤٣.١٧٦جم) ، ووزن الكوز (٣١٠.٩٤٨جم) على الترتيب.
- حققت معاملة إضافة معدل النتروجين عند ١٢٠كجم ن/فدان أعلى محصول حبوب (٣.٥٠٧ طن/فدان) ومحصول الحطب (٩.٣١٣ طن/فدان)، ووزن ١٠٠ حبة (٤٣.٨٩٩جم) ، ووزن الكوز (٣١٦.١١٩جم) على الترتيب.
- سجلت معاملة إضافة السماد النتروجين على ثلاث دفعات أعلى محصول حبوب (٣.٥٨٥ طن/فدان) ومحصول الحطب (٩.٢١٦ طن/فدان)، ووزن ١٠٠ حبة (٤٣.٤٦٦جم) ، ووزن الكوز (٣١٥.٢٠٢جم) على الترتيب.
- بالنسبة لتأثير معاملات الرى على تركيز النيتروجين وامتصاصه بواسطة حبوب وسيقان محصول الذرة الشامية بأن أعلى القيم سجلت تحت معاملة الرى بعد استنفاذ ٤٥% من الماء الميسر.
- مع إضافة معدلات النتروجين زاد تركيز النتروجين والممتص منة لكل من الحبوب والسيقان حتى معدل ١٢٠كجم ن/فدان.
- زاد تركيز النتروجين والممتص منة لكل من الحبوب والسيقان حتى ثلاث دفعات إضافة للسماد النتروجيني.
- زادت قيم كفاءة استخدام النتروجين ب ١٥.٦٥% مع زيادة عدد دفعات إضافة السماد النتروجيني إلى ثلاث دفعات، فى حين قلت القيم مع زيادة إضافة معدل النتروجيني والرى بعد استنفاذ ٧٥% من الماء الميسر.
- كان للتفاعل بين معاملات الرى ومعاملات إضافة السماد النتروجيني وعدد دفعات الإضافة تأثيرا معنويا على كل من المحصول ومكوناته والنتروجين الممتص بواسطة كل من الحبوب والسيقان.

قام بتحكيم البحث

أ.د / احمد عبد القادر طه	**كلية الزراعة – جامعة المنصورة**
أ.د / علي أحمد عبد السلام	**كلية الزراعة بمشتهر– جامعة بنها**