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7 Effect of Withholding Irrigation and Nitrogen Fertilization Level on Maize Yield

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THIS INVESTIGATION was carried out in an demonstrated field at Al-Ibrahimia District, Sharkia Governorate, Egypt, during 2014 and 2015 seasons. The study aimed to find out the effect of withholding one irrigation at five stages as growth and three levels of N fertilization on maize (*Zea mays* L.) yield and yield attributes. Withholding irrigation had significant effect on growth, yield and yield attributes of maize. Skipping the 3rd, 5th or 7th irrigations reflected a significant decrease in both ear diameter and length, grain number per row, 100-grain weight, grain weight per ear, maize yield per fad and harvest index. The increase of N level up to 120 kg N/ fad gave significant increase in grain yield and almost all yield attributes and grain quality properties except harvest index which was decreased. The interaction between irrigation treatments and N levels affected grain yield per fad and some of its attributes where more N was needed for the maize stressed plants due to irrigation withholding. The grain yield response to N level was diminishing where 86.67 kg N/ fad were needed to maximize the grain yield to 5.12 ton/ fad in normally irrigated plants.

Keywords Maize, Withholding Irrigation, Nitrogen, Grain Quality.

INTRODUCTION

In Egypt, the ever growing population dictates a continuous increase in the cultivated area. This increase necessitates a progressive increase in irrigation water which already showed a great shortage. The 55.5 milliar m^3 of water received through the river Nile do not satisfy the needs of the possible extension in the cultivated area. Therefore, efforts should always be paid to optimize the use of water in all activities and in particular in agriculture which receives the great part of available water resources. Therefore, the present study is one of the many attempts which must be devoted to optimize the use of irrigation water. This optimization is always made through keeping down the consumptive use through minimizing the amounts given per irrigation. Skipping one or more irrigation was always tried in order to optimize the use of irrigation water. Ibrahim & Kandil (2007) reported that, the highest averages of plant height, ear characters (length, diameter and weight) as well as ears and grain yields of corn plants/fad were obtained under irrigation interval of 10 days followed by 14 and 18 days. Similarly, the highest values of grain chemical constituents of maize, *i.e.*, total P, total N, carbohydrate and crude protein were obtained under the shortest irrigation interval. Also, Elzubeir & Mohamed (2011) and Sokht-Abandani & Ramezani (2012) reported that, water deficit irrigation in maize led to a significant decrease in numbers of row/ ear and number of grains/ row and ear. El-Shahed *et al.* (2013) revealed that, applying 6 irrigations gave the highest means of the different studied characters, *i.e.* growth and grain yield attributes followed by missing the 4th and 6th irrigations. On the other hand, Sokht-Abandani & Ramezani (2012) found that, ear diameter and length did not show a significant decrease due to prolonging the irrigation interval.

Mineral fertilization with nitrogen was also reported to increase growth and grain yield of maize. El-Murshedy (2002) and El-Sobky *et al.* (2014) reported that, the increase of N level up to 140 and 120 kg N/ fad increased grain yield and its components, *i.e.* number of rows/ ear, number of grains/ row and ear, 100 kernels weight, grain weight and maize grain yield. Also, Atia & Mohamed (2006); Sokht-Abandani & Ramezani (2012); Darwich (2013) and Hameedi *et al.* (2015) showed that, application of mineral N increased maize grain yield, biomass and its components of maize yield and its attributes. The

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present study was devoted to find out the response of white maize yield to the effect of withholding one irrigation at five stages of maize growth compared with a control given seven irrigation at 12 days interval under three levels from N (40, 80 and 120 kg N/ fad) and their interactions.

MATERIALS AND METHODS

The present study was conceded in an demonstrated field at Al-Ibrahimia District, Sharkia Governorate, Egypt, during 2014 and 2015 seasons. The study aimed to find out the effect of five irrigation withholding treatments and three levels of N fertilization on maize yield and yield attributes.

Studied Factors

Irrigation withholding treatments

Normal irrigation, receiving seven irrigations at 12 days interval.

Withholding the 3rd irrigation at 46 days after planting (DAP)

Withholding the 4th irrigation (58 DAP).

Withholding the 5th irrigation (70 DAP).

Withholding the 6th irrigation (82 DAP).

Withholding the 7th irrigation (94 DAP).

*Nitrogen fertilization level*s

1. 40 kgN/fad
2. 80 kgN/fad
3. 120 kg N /fad

N levels were split and partly added before the first (22 DAP) and second (34 DAP) irrigations as ammonium nitrate (33.5% N).

Experimental design

A split plot design of four replications was used, where the irrigation withholding treatments were allocated in the main plots and N fertilization levels were allocated in sub plots (17.5 m^2). Main plots were surrounded by wide borders (2 m) to avoid seepage of water among irrigated and un irrigated plots.

Recorded data

Maize yield and yield attributes

At harvest, (120 days from planting), the following yield attributes were recorded on ten plants and ears: ear diameter (cm), ear length (cm), rows number per ear, grains number per row, grains number per ear (calculated), 100-grain weight (g), shelling (%) and grain weight per ear (g). Also, the following final yield traits were recorded from the two central ridges: grain yield (ton/fad): at grain moisture content of 15.5 %, ears yield, total yield, stover yield (ton/fad) and harvest index (%) *i.e.,* grain to total yield in percentage.

Grain samples at harvest were dried at 70°C up to constant weight where their contents from total N and total carbohydrates were determined, using the colorimeterical method according to Jackson (1967).

General agronomic practices

Single cross 10 maize cultivar (white) was planted on May 17th in both seasons. Each sub plot (3.5m x 5m) included 5 ridges 60 cm apart. Maize seeds were hand sown in hills 25 cm apart on one side of the ridge. Planting was made after Egyptian clover (*Trifolium alexandrinum* L.) as a preceding crop in both seasons using seeding rates of 10 kg/ fad where plants were thinned to one plant per hill (28000 plant/ fad) before the first irrigation (22 DAP) and flood irrigation was practiced every 12 days. Soil samples were collected from the experimental sites at the depth of 0 -30 cm before planting to determine soil physical and chemical properties at the Central Laboratory of Faculty of Agriculture, Zagazig University, Zagazig, Egypt (Table 1).

Statistical analysis

Data were statistically analyzed according to Gomez & Gomez (1984) by using MSTAT-C (1991) where statistical program Version 2.1 was used for analysis of variance (ANOVA). A combined analysis was undertaken for the data of the two seasons after testing the homogenity of the experimental errors. Treatment means were compared according to least significant differences (LSD) test. In the tables of the analysis of variance *,** indicate significant at 0.05 and 0.01 levels of probability, respectively as described by Sendecor & Cochran (1982). In interaction Tables, capital and small letters were used to denote significant differences among rows and columns means, respectively. Interaction Tables are provided with response equations to compare the response of maize yield and its attributes to the increase of N level at the different irrigation treatments. The predicated maximum trait average ($\hat{Y}$max) which could have been obtained due to the addition of the predicted maximum N level (Xmax) are also included. The response equations were calculated according to Snedecor & Cochran (1967) using the orthogonal polynomial Tables. The significancy of the linear and quadratic components of each of these equations was tested, then the response

could be described as linear (first order) or quadratic (second order). The predicted maximum averages (Ŷmax) which could have been obtained due to the addition of the predicted maximum N level (Xmax) were calculated according to Neter *et al.* (1990) as explained by Abdul Galil *et al.* (2003) using the following equations:

$$\hat{Y}_{max} = \hat{Y}_0 + b^2 / 4c \qquad X_{max} = X_0 + b / 2c\ (u)$$

where: $\hat{Y}_0$ = Grain yield at the lowest N level, *i.e.* 40 kg N/ fad (ton/ fad).

b = Measures the linear component of the response equation.

c = Measures the quadratic component of the response equation.

u = unit of N = 40 kg N/ fad.

Data in Table 2 show the monthly mean minimum and maximum air temperatures, relative humidity, wind speed and precipitation during the two maize growing seasons.

TABLE 1. Physical and chemical analyses of the experimental soil sites at 30 cm depth (average of two seasons).

Organic matter (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	pH[a]	Texture
2.10	45	8.0	140	7.90	Clay

a: Soil suspension

TABLE 2. Monthly mean minimum and maximum air temperatures, relative humidity, wind speed and precipitation at Al-Ibrahimia District during the two maize growing seasons *

Month	Temperature (°C)			Relative humidity (%)	Wind (km/h)	Precipitation (mm)
	Max.	Min.	Mean			
2014 season						
May	42	25	33.5	71	13	0.00
June	43	29	36	73	12	0.00
July	39	31	35	82	10	0.00
August	38	32	35	83	10	0.00
September	39	28	33.5	74	9	0.00
2015 season						
May	44	27	35.5	76.4	10	0.00
June	40	28	34	77.4	10	0.00
July	41	30	35.5	85.2	8	0.00
August	42	33	37.5	80.9	10	0.00
September	39	33	36	78.7	10	0.00

* http:// www.wunderground.com

RESULTS AND DISCUSSION

Ear diameter and length

Irrigation withholding treatments effect

The data presented in Table 3 revealed that, irrigation withholding was highly significant affecting both of ear diameter and length. The highest average of ear diameter was found under normal irrigation treatment and it was at par with withholding 4th or 6th irrigation treatments, according to the combined analysis. Missing the 3rd and 7th irrigation detected a significant decrease in both ear diameter and length. These results refer to a decrease in the current and stored photosynthates available for ear growth. Withholding the 3rd irrigation coincided with early plant elongation whereas withholding the 7th irrigation coincided with effective grain filling. These results are agreement with those reported by Hussein & El-Melegy (2006) and Ibrahim & Kandil (2007). However, Sokht-Abandani & Ramezani (2012) found that ear diameter and length did not show significant differences as affected by irrigation intervals.

Nitrogen level effect

In both seasons and their combined, the increase of N level was followed by a significant

TABLE 3. Ear diameter and length of maize as affected by irrigation withholding and nitrogen fertilization level and their interactions in the two seasons.

Main effects and interactions	Ear diameter (cm)			Ear length (cm)		
	2014	2015	Combined	2014	2015	Combined
Irrigation withholding(I):						
Control	4.73 a	4.78 a	4.76 a	20.33 a	21.0 a	20.67 a
Withholding the 3rd irrigation	4.68 ab	4.65 ab	4.66 b	19.58 b	19.86 b	19.72 b
Withholding the 4th irrigation	4.75 a	4.73 a	4.74 a	20.94 a	20.61 a	20.78 a
Withholding the 5th irrigation	4.61 ab	4.63 b	4.62 b	20.58 a	20.64 a	20.61 a
Withholding the 6th irrigation	4.70 a	4.73 a	4.72 a	20.67 a	20.89 a	20.78 a
Withholding the 7th irrigation	4.59 b	4.66 ab	4.63 b	19.67 b	19.67 b	19.67 b
Nitrogen level (N):						
40 kg N/ fad	4.71 a	4.65 b	4.68 b	19.49 b	19.46 c	19.47 c
80 kg N/ fad	4.62 b	4.68 b	4.65 b	20.54 a	20.51 b	20.53 b
120 kg N/ fad	4.71 a	4.75 a	4.73 a	20.86 a	21.36 a	21.11 a
Interactions:						
I x N	N.S.	*	N.S.	N.S.	**	**

*,** and N.S. indicate significancy at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

increase in both ear diameter and length. This response was in keeping up to the addition of 120 kg N/fad (Table 3). Similar results were reported by Darwish (2003),Ash-Shormillesy (2005), Soliman & Gharib (2011), Sokht-Abandani & Ramezani (2012) and El-Sobky *et al.* (2014).

Interaction effect

Results in Table 4 clearly indicate that maize plants were in need for more N up to 120 kg N/ fad in order to compensate for the shortage of water caused by withholding the 3rd irigation. Normally irrigated plants or those missing the 5th or the 6th irrigation did not respond to the increase of N level indicating their normal performance regarding the growth of their ears.

Rows number per ear, grains number per row and ear

Irrigation withholding treatments effect

According to the combined analysis, withholding the 5th irrigation, *i.e.* at 70 DAP, significantly decreased the number of grains per ear probably due to the decrease in the

TABLE 4. Ear length (cm) of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	A	A
	20.17 a	20.83 a	21.00 a
Withholding the 3rd irrigation	B	B	A
	18.50 b	19.50 b	21.17 a
Withholding the 4th irrigation	B	AB	A
	19.83 a	20.83 a	21.67 a
Withholding the 5th irrigation	A	A	A
	20.00 a	20.83 a	21.00 a
Withholding the 6th irrigation	A	A	A
	20.50 a	20.17 ab	21.67 a
Withholding the 7th irrigation	B	A	A
	17.83 b	21.00 a	20.17 a

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

TABLE 5. Rows number per ear, grains number per row and ear of maize as affected by irrigation withholding and nitrogen fertilization level and their interactions in the two seasons

Main effects and interactions	Rows number/ ear			Grains number/ row			Grains number/ ear		
	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined
Irrigation withholding(I):									
Normal irrigation	12.89	12.89	12.89	45.95 a	46.50 a	46.22 a	591.8	599.8	595.8 a
Withholding the 3rd irrigation	12.83	13.17	13.00	43.86 b	44.25 ab	44.05 b	563.1	583.1	573.1 ab
Withholding the 4th irrigation	12.95	12.61	12.78	46.08 a	45.59 a	45.83 a	597.2	575.5	586.3 a
Withholding the 5th irrigation	12.50	13.06	12.78	44.17 b	44.05 b	44.11 b	552.7	575.8	564.2 b
Withholding the 6th irrigation	12.95	13.06	13.00	45.94 a	45.17 ab	45.56 a	593.8	589.2	591.5 a
Withholding the 7th irrigation	12.67	13.11	12.89	45.94 a	44.72 ab	45.33 a	581.7	584.1	582.9 a
Nitrogen level (N):									
40 kg N/ fad.	13.06	13.17	13.11	43.61 c	42.94 c	43.28 c	570.0 b	565.1 c	567.6 c
80 kg N/ fad.	12.58	12.86	12.72	45.49 b	45.13 b	45.31 b	572.4 b	580.6 b	576.5 b
120 kg N/ fad.	12.75	12.92	12.83	46.87 a	47.07 a	46.97 a	597.7 a	608.0 a	602.8 a
Interactions:									
I x N	N.S.	N.S.	N.S.	**	**	**	**	**	**

*, ** and N.S. indicate significancy at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

number of grains per row but not the number of rows per ear which did not vary significantly due to withholding any irrigation (Table 5). Similar results are reported by Elzubeir & Mohamed (2011) and Sokht-Abandani & Ramezani (2012).

Nitrogen level effect

In both seasons and their combined analysis, the number of rows per ear was not significantly increased due to the increase of N level (Table 5). However, number of grains per row and ear were increased significantly due to each N increase up to the addition of 120 kg N/ fad. Moreover, these results refer to more photosynthesis which might had been available for grain set. Similar findings were reported by El-Metwally *et al.* (2001), Bader *et al.* (2003), Abd-Alla (2005), El-Azab (2012) and El-Sobky *et al.* (2014).

Interaction effect

The results in Tables 6 and 7 clearly indicate that withholding irrigation and in particular the 4th or the 7th irrigation might have had subjected maize plants to a decrease in N uptake which was compensated by more addition from N up to 120 kg N/ fad. This response was not seen in the normally irrigated plants. Similar effects were observed in ear length (Table 4).

100-grain weight, grain weight per ear and grain yield

TABLE 6. Grains number per row of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	A	A
	45.67 a	47.00 a	46.00 ab
Withholding the 3rd irrigation	B	B	A
	42.83 b	42.50 b	46.83 ab
Withholding the 4th irrigation	B	A	A
	42.83 b	46.67 a	48.00 a
Withholding the 5th irrigation	B	B	A
	43.00 b	43.50 b	45.83 b
Withholding the 6th irrigation	A	A	A
	44.83 a	45.50 a	46.33 ab
Withholding the 7th irrigation	C	B	A
	40.50 c	46.67 a	48.83 a

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

TABLE 7. Grains number per ear of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	A	A
	594.7 a	610.3 a	582.3 ab
Withholding the 3rd irrigation	B	B	A
	554.7 ab	540.3 b	624.3 a
Withholding the 4th irrigation	C	B	A
	544.0 b	591.3 a	623.7 a
Withholding the 5th irrigation	A	B	AB
	575.0 a	551.7 ab	566.0 b
Withholding the 6th irrigation	A	A	A
	584.7 a	589.0 a	600.7 a
Withholding the 7th irrigation	C	B	A
	552.3 ab	576.3 a	620.0 a

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

Irrigation withholding treatments effect

Irrigation withholding had significant effect on 100-grain weight, grain weight per ear and grain yield per fad (Table 8). Missing the 3rd or the 7th irrigation caused a significant decrease in both 100-grain weight and grain weight per ear maybe due to the coincidence of missing irrigations with restriction of grains number per row and grain filling, as was expected and repeatedly seen in all yield attributes. Grain yield per fad was significantly decreased by missing 3rd or the 7th irrigation by 10.35 and 16.20 %, respectively. This could be attributed to the decreased of grain yield per fad which was significantly decreased with missing the 3rd and 7th irrigation. These results are in close agreement with the results obtained by Ibrahim & Kandil (2007), Elzubeir & Mohamed (2011) and El-Shahed e*t al.* (2013).

Nitrogen level effect

According to the combined analysis, each increase in N level was positively led to an increase in 100-grain weight and grain yield per fad (Table 8). The consistent increase of grain yield/ fad, with each increase in N level could be attributed to the increase of grain yield components (Tables 5 and 8). Similar findings were reported by Atia & Mohamed (2006), Sokht-Abandani & Ramezani (2012), Darwich (2013) and Hameedi *et al.* (2015).

Interaction effect

Results in Tables 9 show that grain weight/ ear

TABLE 8. 100.8- grain weight, grain weight per ear and grain yield per fad of maize as affected by irrigation withholding and nitrogen fertilization level and their interactions in the two seasons

Main effects and interactions	100- grain weight (g)			Grain weight per ear (g)			Grain yield (ton/ fad)		
	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined
Irrigation withholding(I):									
Normal irrigation	38.92 a	39.67 a	39.30 a	227.3 a	232.7 a	230.0 a	4.96 a	5.08	5.02 a
Withholding the 3rd irrigation	36.18 ab	34.84 b	35.51 b	199.5 ab	196.5 b	198.0 ab	4.49 ab	4.50	4.50 ab
Withholding the 4th irrigation	39.79 a	37.29 a	38.54 a	231.8 a	211.5 ab	221.7 a	5.11 a	4.69	4.90 a
Withholding the 5th irrigation	37.65 a	36.86 a	37.26 a	211.3 a	207.8 ab	209.5 a	4.65 a	4.62	4.64 a
Withholding the 6th irrigation	37.90 a	38.24 a	38.07 a	225.5 a	228.5 a	227.0 a	4.86 a	4.74	4.80 a
Withholding the 7th irrigation	35.13 b	35.21 ab	35.17 b	190.5 b	203.5 ab	197.0 b	4.18 b	4.46	4.32 b
Nitrogen level (N):									
40 kg N/ fad.	36.40 b	36.37	36.38 b	202.3 b	197.3 b	199.8 c	4.47 b	4.44 c	4.46 c
80 kg N/ fad.	37.63 ab	36.79	37.21 b	217.4 a	214.1 a	215.8 b	4.77 a	4.74 b	4.76 b
120 kg N/ fad.	38.76 a	37.91	38.33 a	223.3 a	228.8 a	226.0 a	4.88 a	4.87 a	4.87 a
Interactions:									
I x N	**	N.S.	N.S.	**	**	**	**	**	**

*, ** and N.S. indicate significancy at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

was significantly increased in only those plants which were subjected to shortage of water due to withholding any irrigation except the 5th irrigation. This effect was also reflected in the response of grain yield per fad (Table 10) to the increase to N level. The response was quadratic in most cases where 86.67 kg N/ fad were enough to maximize yield to 5.12 ton/ fad in normally irrigated plants whereas 100.4 kg N/ fad were needed to maximize yield to 4.78 ton/ fad when the 7th irrigation was withhold.

Ears, stover and total yields and harvest index

Irrigation withholding treatments effect

The results summarized in Table 11 revealed that, according to combined analysis, irrigation withholding significantly affected ears, stover and total yields. Ears yield was decreased by 14.78% when missing the 7th irrigation and both the stover and the total yields/fad were decreased by 22.66, 19.51 and 17.73, 17.27% when missing the 3rd or the 7th irrigation, respectively compared with normal irrigation treatment. Similar significant effects were observed in some yield attributes (Tables 3, 5 and 8). While, missing the 5th irrigation led to a significant decrease in harvest index. These results are in accordance with those reported by Ibrahim & Kandil (2007), Farre & Faci (2009) and Iqbal *et al.* (2010).

Nitrogen level effect

Addition of 120 kg N/ fad produced a significant increase in ear yield/ fad in the second season and the combined analysis. However, stover and total yields/ fad did not show significant difference between adding 80 or 120 kg N/fad. But, the combined analysis detected significant decrease in harvest index due to the increase of N level to 80 or 120 kg N/ fad which produced at par significant decrease in harvest index (Table 11). Similar results were obtained by Mohamed (2006), Achieng *et al.* (2010), El-Azab (2012) and Sokht-Abandani & Ramezani (2012), Abd El-Rheem *et al.* (2015) and Mahama *et al.* (2016).

TABLE 9. Grain weight per ear (g) of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	A	A
	227.0 a	230.0 a	233.0 ab
Withholding the 3rd irrigation	B	B	A
	191.0 a	189.0 b	214.0 b
Withholding the 4th irrigation	B	A	A
	201.5 a	235.5 a	228.0 ab
Withholding the 5th irrigation	A	A	A
	200.5 a	209.0 ab	219.0 ab
Withholding the 6th irrigation	B	B	A
	218.0 a	220.5 a	242.5 a
Withholding the 7th irrigation	B	A	A
	161.0 b	210.5 ab	219.5 ab

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

TABLE 10. Grain yield (ton/ fad) of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level			$\hat{Y} = a + bx - c\,x^2$	$\hat{Y}_{max}$ (ton/ fad)	X_{max} (kg N/ fad)
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad			
Normal irrigation	A	A	A	$4.92 + 0.35\,x - 0.15\,x^2$	5.12	86.67
	4.92 a	5.12 a	5.02 a			
Withholding the 3rd irrigation	B	B	A	$4.43 + 0.65\,x$	Linear	Linear
	4.43 a	4.21 b	4.85 a			
Withholding the 4th irrigation	B	A	A	$4.46 + 1.39\,x - 0.57\,x^2$	5.31	88.77
	4.46 a	5.28 a	4.96 a			
Withholding the 5th irrigation	B	AB	A	$4.41 + 0.09\,x$	Linear	Linear
	4.41 a	4.58 ab	4.92 a			
Withholding the 6th irrigation	A	A	A	$4.86 - 0.33\,x + 0.16\,x^2$	4.69	81.25
	4.86 a	4.69 a	4.84 a			
Withholding the 7th irrigation	B	A	A	$3.65 + 1.50\,x - 0.5\,x^2$	4.78	100.4
	3.65 b	4.65 ab	4.66 a			

$\hat{Y}_{max}$: predicted maximums average X_{max}: predicted maximum N level

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

TABLE 11. Ears, stover and total yields and harvest index of maize as affected by irrigation withholding and nitrogen fertilization level and their interactions in the two seasons.

Main effects and interactions	Ears yield (ton/ fad)			Stover yield (ton/ fad)			Total yield (ton/ fad)			Harvest index (%)		
	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined
Irrigation withholding(I):												
Normal irrigation	5.89 a	6.01	5.95 a	6.76	7.17 a	6.97 a	12.65	13.18 a	12.91 a	39.26	38.63 ab	38.94 ab
Withholding the 3rd irrigation	5.25 ab	5.22	5.23 ab	6.04	4.74 b	5.39 b	11.28	9.96 b	10.62 b	40.58	46.16 a	43.37 a
Withholding the 4th irrigation	5.96 a	5.48	5.72 a	6.92	6.04 a	6.48 a	12.88	11.52 a	12.20 a	39.81	40.95 ab	40.38 ab
Withholding the 5th irrigation	5.42 a	5.42	5.42 a	6.68	6.83 a	6.76 a	12.10	12.25 a	12.18 a	38.61	37.89 b	38.25 b
Withholding the 6th irrigation	5.68 a	5.54	5.61 a	6.83	6.34 a	6.58 a	12.50	11.88 a	12.19 a	39.22	40.06 ab	39.64 ab
Withholding the 7th irrigation	4.92 b	5.22	5.07 b	5.71	5.52 ab	5.61 b	10.63	10.74 ab	10.68 b	40.68	42.69 a	41.68 a
Nitrogen level (N):												
40 kg N/ fad.	5.23 b	5.18 c	5.20 c	6.08	5.59 b	5.83 b	11.30 b	10.76 b	11.03 b	40.26	42.30	41.28 a
80 kg N/ fad.	5.62 a	5.57 b	5.60 b	6.69	6.18 a	6.44 a	12.31 a	11.75 a	12.03 a	39.06	40.64	39.85 b
120 kg N/ fad.	5.71 a	5.70 a	5.71 a	6.70	6.56 a	6.63 a	12.41 a	12.26 a	12.34 a	39.76	40.25	40.01 b
Interactions:												
I x N	**	**	**	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.		N.S.

*, ** and N.S. indicate significancy at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

Interaction effect

According to the combined analysis ears yield per fad was significantly affected by I x N interaction (Table 12). This interaction effect was observed in the grain yield/ fad (Table 10) and could account for the present interaction indicating the need for more N additions when irrigation was withheld and in particular in the 7th irrigation. Several studies stressed on the need for newly reduced N during grain filling in maize. Shortage of water during post silking needs to be compensated by more N addition (Below *et al.,* 1981).

TABLE 12. Ears yield (ton/ fad) of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	A	A
	5.75 a	6.20 a	5.89 a
Withholding the 3rd irrigation	B	B	A
	5.15 a	4.91 b	5.64 a
Withholding the 4th irrigation	B	A	A
	5.21 a	6.14 a	5.81 a
Withholding the 5th irrigation	B	AB	A
	5.13 a	5.35 b	5.78 a
Withholding the 6th irrigation	A	A	A
	5.69 a	5.44 b	5.70 a
Withholding the 7th irrigation	B	A	A
	4.29 b	5.50 b	5.41 a

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

Grain protein and carbohydrates content

Irrigation withholding treatments effect

According to combined analysis, grain protein and carbohydrates content generally decreased significantly due to irrigation withholding (Table 13). The missing 5th irrigation had the more injury effect on protein content by 5.89 % compared to normal irrigation treatment. It is may be due to the dilution effect. Similar results were reported by Mohsen *et al.* (2012). Normal irrigation or missing 7th irrigation treatment gave higher grain carbohydrates percentage in comparison to other treatments.

Nitrogen level effect

Each increase in N level was reflected in a significant increase in grain protein content up to

the addition of 120 kg N/ fad (Table 13). While, the increase of N level to 80 kg N/ fad produced significant increase in carbohydrates content. These results are in harmony with those reported by Soliman & Gharib (2011), Xiaobin *et al.* (2011), El-Naggar *et al.* (2012) and Darwich (2013).

Interaction effect

According to the combined analysis, grain protein content was significantly affected by I x N interaction (Table 14). The interaction between applying 120 kg N/fad under the missing 6th or 7th irrigations led to a significant increase in grain protein content, followed by 80 kg N/fad under the missing 4th irrigation treatment.

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TTABLE 13. Grain protein and carbohydrates content of maize as affected by irrigation withholding and nitrogen fertilization level and their interactions in the two seasons.

Main effects and interactions	Grain protein content (%)			Grain carbohydrates content (%)		
	2014	2015	Combined	2014	2015	Combined
Irrigation withholding(I):						
Normal irrigation	8.31 b	8.65 a	8.48 a	73.39 a	72.64 a	73.01 a
Withholding the 3rd irrigation	8.32 b	8.22 ab	8.27 ab	68.83 b	70.09 ab	69.46 b
Withholding the 4th irrigation	8.82 a	8.66 a	8.74 a	68.56 b	70.68 ab	69.62 b
Withholding the 5th irrigation	7.89 b	8.07 b	7.98 b	69.61 b	68.59 ab	69.10 b
Withholding the 6th irrigation	8.83 a	8.43 ab	8.63 a	69.37 b	68.29 b	68.83 b
Withholding the 7th irrigation	8.82 a	8.98 a	8.90 a	72.65 a	73.10 a	72.87 a
Nitrogen level (N):						
40 kg N/ fad.	8.26 c	8.11 c	8.18 c	69.64	69.87	69.75 b
80 kg N/ fad.	8.47 b	8.41 b	8.44 b	70.55	70.60	70.57 ab
120 kg N/ fad.	8.77 a	8.99 a	8.88 a	71.02	71.23	71.12 a
Interactions:						
I x N	**	**	**	N.S.	N.S.	N.S.

*,** and N.S. indicate significancy at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

TABLE 14. Grain protein content (%) of maize as affected by irrigation withholding and nitrogen fertilization level interaction (combined data).

Irrigation withholding	N level		
	40 kg N/ fad	80 kg N/ fad	120 kg N/ fad
Normal irrigation	A	B	A
	8.67 a	8.06 b	8.70 a
Withholding the 3rd irrigation	B	A	A
	7.19 b	8.41 b	8.50 ab
Withholding the 4th irrigation	B	A	A
	7.88 a	9.20 a	9.14 a
Withholding the 5th irrigation	B	A	A
	7.50 ab	8.38 b	8.06 b
Withholding the 6th irrigation	B	B	A
	8.20 a	8.26 b	9.44 a
Withholding the 7th irrigation	B	C	A
	8.94 a	8.32 b	9.44 a

Mean values in the same column for each trait followed by the same lower-case letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

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تأثير إسقاط الري ومستوي التسميد النيتروجيني علي محصول الذرة الشامية

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أجريت هذه الدراسة خلال الموسمين الزراعيين 2014 - 2015 بحقل إرشادي بمركز الإبراهيمية محافظة الشرقية ، وذلك بهدف دراسة تأثير إسقاط ريه واحدة خلال خمس مراحل نمو مختلفة ، حيث تم استخدام ستة معاملات إسقاط ري وهي (الكنترول بدون إسقاط ري - إسقاط الريه الثالثة - إسقاط الريه الرابعة - إسقاط الريه الخامسة - إسقاط الريه السادسة - إسقاط الريه السابعة). كذلك دراسة تأثير مستوي التسميد النيتروجيني (40 ، 80 و 120 كجم ن/ فدان) وذلك علي محصول الذرة الشامية ومساهماته. ويمكن تخليص النتائج المتحصل عليها علي النحو التالي:

- كان لإسقاط الري تأثيراً معنوياً علي محصول الذرة الشامية ومؤشرات المحصول. حيث لوحظ وجود إنخفاض معنوي في كل من طول وقطر الكوز، عدد حبوب السطر، وزن 100 حبة، وزن حبوب الكوز، محصول الحبوب/ فدان ودليل الحصاد نتيجة إسقاط الرية الثالثة، الرية الخامسة أو الرية السابعة.
- أدي زيادة مستوي النيتروجين حتي 120 كجم ن/ فدان إلي زيادة معنوية في محصول الذرة الشامية وأغلب مؤشرات المحصول وكذلك صفات جودة الحبوب بإستثناء دليل الحصاد والذي إنخفض بزيادة مستوي التسميد النيتروجيني.
- كان هناك تأثير معنوي لتداخل الفعل بين عوامل الدراسة علي محصول الحبوب/ فدان و بعض مؤشرات المحصول تحت الدراسة ، والذي أتضح منه زيادة احتياجات نباتات الذرة من النيتروجين عند تعرضها لظروف الإجهاد الرطوبي من خلال إسقاط الري. وأوضحت معادلات الاستجابة إمكانية تعظيم محصول حبوب الذرة الشامية إلي 5.12 طن/ فدان بإضافة 86.67 كجم ن/ فدان فقط عند الري كل 12 يوم.