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Irrigation Schedule with Different Nitrogen Sources and Levels for Maize Productivity and Some Water Relations

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TWO FIELD experiments were conducted in two successive summer seasons during 2016 and 2017 at Sids Agricultural Research Station, Beni-Suef Governorate, Egypt. This research was carried out to study irrigation schedule impact using pan evaporation method (Class A pan and irrigation at 0.7, 1.0 and 1.3 pan evaporation coefficient, APE) with different nitrogen sources (ammonia gas, ammonium nitrate and urea) and levels (214 and 286 kg N ha^{-1}) on maize yield attributes as well as some water relations, namely, seasonal applied water (AP), seasonal consumptive use (CU), water utilization efficiency (WUtE) and water use efficiency (WUE). Results showed that increasing pan evaporation coefficient from 0.7 up to 1.3 increased maize yield and improved its attributes, N, P and K uptake by grains and/or stover, seasonal applied water and seasonal consumptive use. The differences between the effect of 1.0 and 1.3 of APE on maize grain and stover yields were not significant. Irrigation at 1.0 APE gave the highest WUtE and WUE followed by irrigation at 1.3 APE. Whereas the lowest one produced under 0.7 of APE Added nitrogen as anhydrous ammonia increased all studied yield and its attributes, N, P and K uptake, seasonal consumptive use, water utilization efficiency and water use efficiency followed by ammonium nitrate, while urea fertilizer exhibited the lowest ones. Increasing nitrogen levels from 214 to 286 Kg ha^{-1} improved maize yield and its attributes, N, P and K uptake as well as the studied water relations. The best treatment for maize productivity and water relation is to irrigate at 1.0 of APE with nitrogen addition as ammonia gas at the rate of 286 Kg ha^{-1}, while saving about 960 m^3 per hectare with no significant decrease in yield. This study confirms that maize irrigation at different pan evaporation coefficient (0.7, 1.0 and 1.3) with different nitrogen fertilization sources and levels affect maize productivity traits and some water relations.

Keywords: Maize attributes, Nitrogen sources and nitrogen levels, Pan coefficient, Water relations.

Introduction

Water is the most limiting natural resource for agricultural production in arid and semi-arid regions. Nowadays the total annual water resource of Egypt is about 67.27 billon m^3 (Hafiz and Ewis, 2015). The agricultural sector consumes almost 80-90% of the total water allocated to Egypt. Therefore, there is a need for decreasing plant water consumption through using more efficient irrigation methods (Tayel *et al*., 2007), plant breeding technology, longer irrigation intervals, higher moisture depletion, skipping during the early vegetative growth or during maturation stage, and timing length of irrigation interval with the stage of plant growth (Faki, 1991). Moreover, Egypt is the 15th most populated country in the world. Its population has tripled during the last 50 years. Egypt receives about 98 per cent of its fresh water from the Nile River originating outside its international border (Zorkany, 2014). The usefulness of evaporation pan to predict soil moisture deficit in field and to estimate the crop water requirement for weekly and long period is discussed in detail by Ashraf *et al*. (2002), Khalil and Mohamed (2006) and Eid *et al.* (2010). El bably (2007) stated that irrigation scheduling of maize at 1.2 of accumulation of pan evaporation significantly increased plant height, ear length, number of rows/ears, number of grains/rows, 100-grain weight and grain yield.

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Nitrogen is an essential nutrient for both maize quantity and quality as it is a component of protein and chlorophyll. It is thus, essential for photosynthesis, vegetative and reproductive growth and it often determines yield of maize (Igbal *et al.,* 2006). Nitrogen for maize cultivation is equally important to realize the yield potential (Sajedi *et al.,* 2009). Among different elements of Egypt soil, nitrogen is the key input for achieving higher yield of maize, but nitrogenous fertilizer may be increased to a certain level and thereafter it has got adverse effect. It was generally observed that maize fail to produce good grains in plots without adequate nutrients. Therefore, the supply of nitrogen is important for maize production as much as water. On the other hand, indiscriminate use of nitrogen leads to increase in production costs and environmental contamination (Gurpreet *et al.,* 2013). Inorganic nitrogen fertilizer exerts strong influence on plant growth, development and yield (Stefano *et al.,* 2004). The availability of sufficient nutrients from inorganic fertilizers lead to improve all activities, enhanced cell multiplication and enlargement and luxuriant growth (Fashina *et al.,* 2002). Luxuriant growth resulting from nitrogen fertilizer application leads to larger dry matter production (Obi *et al*., 2005), owing better utilization of solar radiation and many investigators stated that increasing nitrogen levels were increased growth, yield and its components, and nutrient uptake of maize (Ismail *et al*., 1999; Ismail *et al.,* 2006; Sadik *et al.,* 2009; Ali *et al.,* 2012; Abd El-Hafeez *et al.,* 2013, and Wang and Xing, 2017). In general, increases in soil moisture promote the response of maize yield to nitrogen application, especially al high nitrogen rate (Eck, 1984). Also, N uptake was strongly affected by water supply (Martin *et al*., 1982). Norwood (2000) and El-Sharkawy *et al.* (2006) pointed out that increasing N rate was accompanied with markedly increase in maize grain yield under applied adequate water. In this concern, Eid *et al.* (2010); Azizian and Sepaskhah (2014), and Nilahyana *et al.* (2018) show that nitrogen use efficiency (NUE) increased with decreasing water applied and decreased with increasing N rate.

Maize is one of the most important crops in the world. It is the third major cereal crop after wheat and rice with regard to the world production. However, it is the highest yielding cereal crop known. It is a major feed crop in many countries, because the grains are rich in the energy and its use in the manufacture of many industrial products. Keeping in view, the above said points, field experiments were conducted to examine the interaction irrigation at different pan evaporation coefficient (0.7, 1.0 and 1.3), sources and levels of nitrogen fertilizers on maize productivity and some water relations.

Materials and Methods

The present research trials were conducted during 2016 and 2017 summer seasons at the experimental Farm of Sids Agricultural Research Station, Beni-Suef Governorate, Middle Egypt, Lat.29° 04 N, long 31° 06 E and 30-40 m above the mean sea level. Some physico-chemical properties and soil moisture constants of the experimental sites were determined and listed in Tables 1 and 2 (according to Klute, 1986 and Page *et al*. 1982). Some metrological data of the experimental site which were recorded during two growth seasons of maize plants are illustrated in Table 3. The experimental design was split-split plot design in three factors with four replicates. The factors were:

1- Irrigation scheduling treatments which carried out using the pan evaporation method (Class A pan), the treatments were irrigation at 1.3 (I_1), 1.0 (I_2) and 0.7 (I_3) pan evaporation coefficient.

2- Nitrogen sources, namely, urea (46.5% N, U), ammonium nitrate (33.5% N, AN) and ammonia gas (82% N, AG).

3- Nitrogen levels at rate of 214 and 286 N ha^{-1}.

The irrigation treatments were allocated in main plots and the nitrogen sources were devoted in sub plot, while nitrogen levels were randomly assigned in sub-sub plots. Urea and ammonium nitrate fertilizers were added at two equal doses before first and second irrigations, while ammonia gas treatments were injected directly into soil (at 14% moisture) at 15 cm depth, 30 cm spacing between points of injection before 7 days from sowing. Grains of maize (Zea mays L.) cultivar Single cross 10 were sown in 15th and 20th June in the two seasons, respectively, the experimental plot consisted of five ridges, 4.2 meters in length and 60 cm apart, occupying an area of 12.6 m2 (about 1/794 hectare). The phosphorus fertilizer was added to all plots as calcium superphosphate (15.5% P2O5) at rate of 55 kg P2O5/ha before sowing, while potassium fertilizer was applied as potassium sulphate (48% K2O) at rate of 57 kg K2O/ha in two equal doses, the first after thinning and the second at one month later. Wheat is the preceding crop. All other agricultural practices were applied as done in the region.

At harvesting ten plants were chosen randomly from the inner rows of each plot to measured maize yield components, i.e., number of rows ear^{-1}, number of grains row^{-1} and 100 grain weight. Also, grain and stover yields were determined for each plot and converted to t ha^{-1}. Representative samples were taken from grains and stover to determine N, P and K concentrations according to AOAC (1990), Then N, P and K uptake in grains and/or stover were calculated.

TABLE 1. Some soil physicochemical properties of the experimental site in 2016 and 2017 seasons

Soil properties	2016	2017
Soil particle distribution:		
Particle size distribution:		
Clay (%)	51.11	50.35
Silt (%)	32.36	31.67
Sand (%)	16.53	17.98
Texture grade	Clay	Clay
Chemical properties:		
pH (1:2.5 soil-water suspension)	7.95	8.00
EC, soil paste (dS m^{-1})	1.13	1.23
Organic matter (%)	1.61	1.75
Available N (mg kg)	22.50	23.72
Available P (mg kg)	15.1	17.3
Available K (mg kg)	187	179

TABLE 2. Some soil moisture constants and bulk density of the experimental site

Season	Soil depth (cm)	Field Capacity (% w/w)	Wilting Point (% w/w)	Bulk Density (g cm^{-3})	Available Water (w/w %)	
					W%	mm
2016	0.0-15	46.09	22.36	1.162	23.73	41.36
	15-30	35.91	16.15	1.172	19.76	34.74
	30-45	33.78	15.33	1.176	18.45	32.54
	45-60	31.30	14.92	1.181	16.35	27.74
2017	0.0-15	46.31	23.35	1.179	22.96	40.60
	15-30	38.15	18.97	1.253	19.18	36.05
	30-45	35.19	17.52	1.266	17.67	33.56
	45-60	32.51	16.16	1.315	16.36	32.27

TABLE 3. Some metrological data of the experimental site during both growth seasons of maize plants

Seasons	2016					2017				
Intervals	Air temperature C		Relative humidity%		E.P mm/ day	Air temperature C		Relative humidity%		E.P mm/ day
	Max.	Min.	Max.	Man.		Max.	Min.	Max.	Min.	
01-10/6	33.8	21.1	88	21	7.8	34.1	20.4	75	22	8.0
11-20/6	35.7	21.8	88	22	8.0	34.8	20.5	78	23	8.1
21-30/6	37.3	22.0	87	22	8.1	35.2	21.6	79	24	8.3
01-10/7	40.7	24.2	86	23	8.3	38.8	24.5	74	25	8.4
11-20/7	41.2	25.7	87	24	8.5	40.9	26.3	75	27	8.6
21-31/7	43.1	26.3	87	25	8.7	42.1	26.9	76	27	8.7
01-10/8	42.5	24.9	86	26	8.6	41.6	25.2	75	26	8.5
11-20/8	41.1	24.4	86	29	8.4	40.0	24.8	74	26	8.3
21-31/8	40.9	24.0	87	29	8.3	39.6	24.0	77	24	8.0
01-10/9	39.1	23.3	82	27	7.5	38.5	23.8	81	20	7.5
11-20/9	37.2	22.9	80	27	7.3	37.3	22.7	79	21	7.3
21-30/9	34.3	21.1	80	25	7.2	37.0	21.8	79	22	7.1
01-10/10	33.5	19.9	76	21	6.0	33.2	19.8	70	22	6.5
11-20/10	31.6	19.3	77	19	5.8	30.6	19.1	71	21	6.3
21-31/10	30.1	18.7	78	18	5.6	32.3	18.6	75	24	6.0

Soil and water relationships measurements and calculations

-Time of irrigation

The available water has been converted to water depth in mm as shown in Table (2), it was 136.38 and 142.48 mm for both growth seasons, respectively. At every irrigation event, the equivalent amount of evaporation that can occur was estimated, meanwhile amount of available soil water is being used. Scheduling of irrigation started after applying the first irrigation. Monthly accumulative pan evaporation (APE), number and irrigation intervals are given in Table (4).

-Irrigation water applied (WA)

Irrigation water was calculated by the summation of the daily records of class A pan evaporation.

Seasonal applied irrigation water

Submerged flow orifice with fixed dimension was used to measure the amount of water applied according to Michael, 1978 as the following equation.

$$Q = CA\sqrt{2gh}$$

where:
Q = discharge through orifice (L/sec.).
C = coefficient of the discharge (0.61).
A = cross-section area of orifice (cm^2).
g = acceleration of gravity (980cm/sec2).
h = pressure lead causing discharge through the orifice (cm).

TABLE 4. Accumulative pan evaporation (APE) number and irrigation intervals during both growing seasons

Seasons	2016				2017			
Interval of APE	APE mm/day	Irrigation at APE of			APE Mm/ day	Irrigation at A.P.E of		
		0.7 (I_3) 194.9mm	**1.0 (I_2) 136.4mm**	**1.3 (I_1) 104.9mm**		**0.7 (I_3) 203.6mm**	**1.0 (I_2) 142.5mm**	**1.3 (I_1) 109.6mm**
1-10/6	7.8				8.0			
11-20/6	8.0		Sowing date 15/6		8.1		Sowing date 20/6	
21-30/6	8.1				8.2			
			6/7 first irrigation (20)				11/7 first irrigation (20)	
1-10/7	8.3	29/7(23)	21/7(16)		8.3			
11-20/7	8.5	17/7(12)			8.4			27/7(17)
21-31/7	8.7			29/7(12)	8.6	3/8 (24)		
						23/7 (13)		
1-10/8	8.6	21/8(23)	6/8(16)		8.2		13/8(17)	5/8(13)
11-20/8	8.4			10/8(12)	8.1	28/8(25)	31/8(18)	29/8(14)
21-31/8	8.3	14/9(25)	22/8(16)		8.0		20/9(20)	
1-10/9	7.5			23/8(13)	7.4			
11-20/9	7.3		8/9(17)		7.2	25/9(28)		13/9(15)
21-30/9	7.2			5/9(14)	7.0			29/9(16)
Total number of irrigations		5	6	7		5	6	7

The figures shown in between brackets indicate the irrigation intervals in days.

TABLE 4a. Seasonal water applied (m3 ha-1) as affected by irrigation treatments for both seasons

No of irrigation	Irrigation treatments					
	1.3 APE (I1)		1.0 APE (I2)		0.7 APE (I3)	
	2016	2017	2016	2017	2016	2017
Sowing irrigation	1326	1308	1326	1308	1326	1308
Live irrigation	1040	1015	1040	1015	1040	1015
Third irrigation	1101	1076	1107	1048	1050	1030
Fourth irrigation	1139	1081	1136	1107	1465	1349
Fifth irrigation	1164	1128	1241	1207	1229	1218
Sixth irrigation	1124	1104	1160	1135	-----	-----
Seventh irrigation	1106	1038	-----	-----	-----	-----
Total	8000	7750	7010	6820	6110	5920

TABLE 4b. Number and irrigation intervals as affected by irrigation treatments

Irrigation treatments	No. of irrigation	Irrigation intervals, days 2016							Irrigation intervals, days 2017						
1.3 APE (I1)	7	Sowing	20	12	12	12	13	14	Sowing	20	13	13	14	15	16
1.0 APE (I2)	6	Sowing	20	16	16	16	17	---	Sowing	20	17	17	18	20	---
0.7 APE (I3)	5	Sowing	20	23	23	25	---	---	Sowing	20	24	25	28	---	---

Crop – water relation parameters

- Seasonal consumptive use (CU)

To determining the crop water consumptive use, soil samples were taken just before irrigation, 48 hours after each irrigation event and at harvest in 15 cm increment system to 60 cm depth of the soil profile. The crop water consumptive use between each two successive irrigation was calculated according to Israelsen and Hansen (1962) as follow:

$$CU = \frac{D.\ Bd\ (Q_2\text{-}Q1)}{100}$$

where:

CU = Actual consumptive use (cm).

D = Effective root zone depth (cm), 60 cm.

Bd = Bulk density of depth (g/cm-3).

Q_2 = Soil moisture percentage (wt/wt) two days after irrigation.

Q_1 = Soil moisture percentage (wt/wt) just before the next irrigation.

The time need for each plot was recorded.

- Water use efficiency (WUE)

The water use efficiency as water consumed per kg seed maize/m^3 was calculated for each treatment following the formula described by Vites (1965).

$$WUE\ (kg/m^3) = \frac{\text{Maize grain yield (kg ha}^{-1})}{\text{Consumptive use (m}^3\text{ ha}^{-1})}$$

- Water utilization efficiency (Water productivity, WP)

Water productivity is an efficiency term calculated as a ratio of product water output over water input. Water productivity in the present study is expressed as kilogram of maize grain yield per unit of applied irrigation water (FAO, 2003).

$$WP = (kg/m^3) = \frac{\text{Maize grain yield (kg ha}^{-1})}{\text{Water applied (m}^3\text{ ha}^{-1})}$$

Statistical analysis

The obtained data were statistically analyzed by analysis of variance according to method described by Snedecor and Cochran (1980). Duncan's multiple range for comparing the differences between treatment means was used at the probability level of 0.05.

Results and Discussion

Yield components

Data in Table 5 represent the effect of irrigation scheduling, nitrogen sources and levels on yield components of maize. The data indicated that irrigation at 1.3 (I_1) accumulative evaporation (APE) gave statistically number of rows/ear, number of grains/row and 100-grain weight equal to those under I_2 and higher than I_3. The reduction of these parameters resulted to decrease moisture content (I_3) reached to 2.7, 6.2 and 14.6% over (I_2), respectively in the first season. The corresponding decreasing in the second season were 2.4, 6.1 and 14.5% in the same order. It is obvious to notice that effect of the reduction of moisture content was more pronounced in the weight of grains than the other two yield component parameters. These reductions in yield component parameters may be due to water shortage that causes the close of the stomata and reduce all metabolism process within plant tissues (Eid *et al*., 2010). Also, Kuchenbuch *et al*. (2006) and Sangakkara *et al*. (2010) mentioned that, the lack of sufficient soil moisture affects growth and development of roots. Similar results were obtained by Galbiatti *et al*. (2004) and El-Tantawy *et al*. (2007) who reported that yield components of maize plants were gradually increased as a result of increasing soil moisture content.

As for different nitrogen sources, the data reveal that all studied maize yield components were significantly affected by nitrogen fertilizer sources. It could be arranged that the effect of nitrogen sources on yield components in descending order as follow: ammonia gas > ammonium nitrate > urea. The superiority of ammonia gas than other two nitrogen fertilizers may due to the promoted effect of anhydrous ammonia on decreasing soil pH caused by injection of anhydrous ammonia which enhanced nutrient uptake. In this connection, Sommer (2005) mentioned that the roots absorbed nitrogen out of there only if they are sufficiently supplied with saccharides from the aboveground parts and plant can thus use nitrogen in metabolism of nitrogenous compounds. The roots that participate in uptake of nitrogen and ammonia from depots, (the injection of liquid ammonia fertilizer into soil in limited points of application creating so-called depots) become denser and branch due to saccharides produced in the aboveground part of plant. Also, roots distribution changes in accordance with plant growth stage and they usually grow from free soil towards depots. These results are in line with those obtained by Ismail et al (1996) and El-Masry et al (2006).

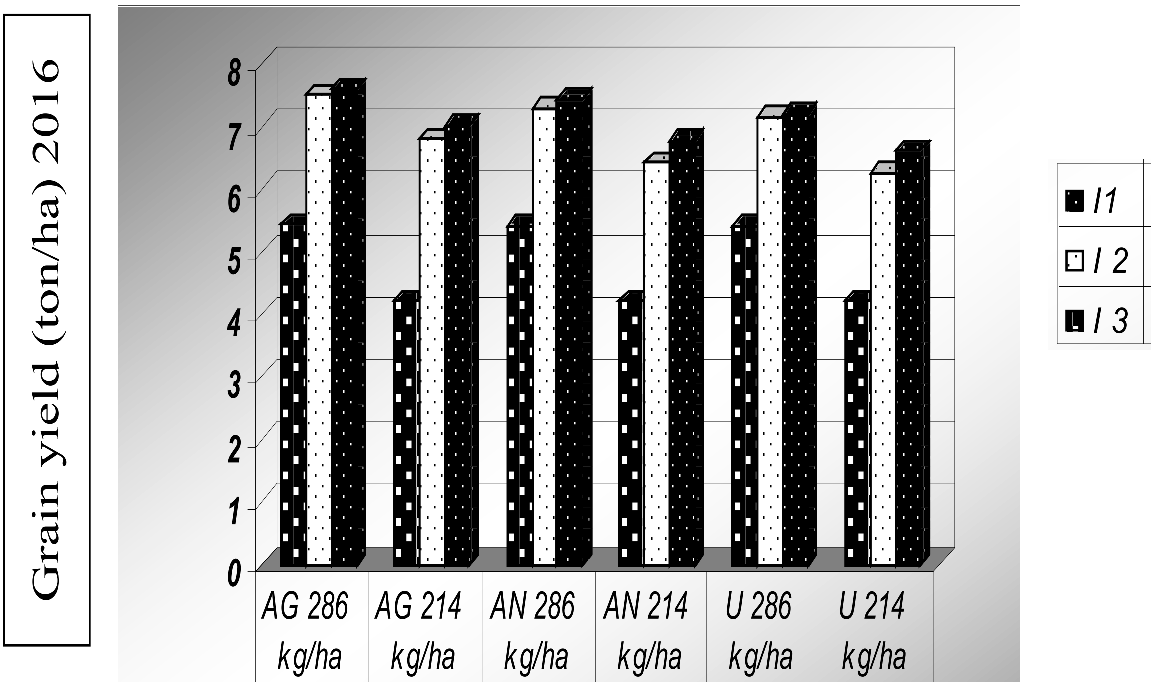
Concerning the nitrogen levels, the data show that, regardless the nitrogen sources, increasing nitrogen levels gradually increased maize yield components. In the first season, added 286 Kg N ha^{-1} increased number of rows/ear, number of grains/row and 100-grain weight by about 0.8, 4.7 and 8.09% when compared with 214 kg N ha^{-1}, respectively. Same trends were obtained in the second season. The promotive effect of increasing nitrogen levels on maize yield components is mainly due to merestmic activity, vegetative growth and accumulation of photosynthates resulted by nitrogen (Dubey *et al*., 2013). These results agree with those obtained by El-Zubair *et al*. (2015) and Jat *et al*. (2017).

Grain and stover yields

Data in Fig. (1 and 2) represent the effect of irrigation and nitrogen sources and levels on grain and stover yield of maize. It is evident from the data that irrigation treatments had significantly affected maize yields. It was observed that irrigation at 1.3 APE gave higher grain and stover yields over irrigation at 1.0 and 0.7 APE. The maximum grain and stover yields recorded in irrigation at 1.3 APE were 7.049 and 7.865 t ha^{-1} in the first season and 7.112 and 7.938 t ha^{-1} in the second one, respectively, followed by that irrigation at 1.0 PAE (6.826 and 7.754 t ha^{-1} in the first season and 6.911 and 7.858 t ha^{-1} in the second season, respectively, with no significant differences between them. On the other hand, the irrigation at 0.7 PAE yielded the lowest grain and stover yields. The higher grain and stover yields with increasing levels of irrigation might be due to the significant enhancement in yield components as mentioned before and also to the availability of water as an important factor in the plant growth. The reduction in maize yields resulted in decreasing the availability of soil moisture content (I_3 treatment) and could be attributed to water shortage (Eid *et al*., 2010). These results are similar to those obtained by Shinde *et al*. (2014) and Ewis *et al*. (2016).

TABLE 5. Means of yield components of maize plants as affected by irrigation schedule and nitrogen sources and levels

Treatments	Number of row/ear		Number of grains/row		100-grain weight (g)	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	12.98 b	13.03 b	45.29 a	45.34 a	30.28 a	29.91 a
I2 (1.0 APE)	13.12 a	13.15 a	44.60 b	44.68 b	29.87 b	29.96 a
I3 (0.7 APE)	12.76 c	12.83 c	41.85 c	41.97 c	25.52 c	25.63 b
N sources						
Urea	12.90 c	12.92 c	43.81 c	43.90 c	28.21 c	28.04 c
A. N.	12.95 b	13.00 b	43.95 b	44.03 b	28.60 b	28.44 b
A. G.	13.01 a	13.09 a	44.04 a	44.11 a	28.96 a	29.02 a
N levels						
214 kg/ha	12.90 b	12.94 b	42.93 b	43.03 b	27.44 b	27.64 b
286 kg/ha	13.00 a	13.05 a	44.93 a	44.99 a	29.66 a	29.42 a



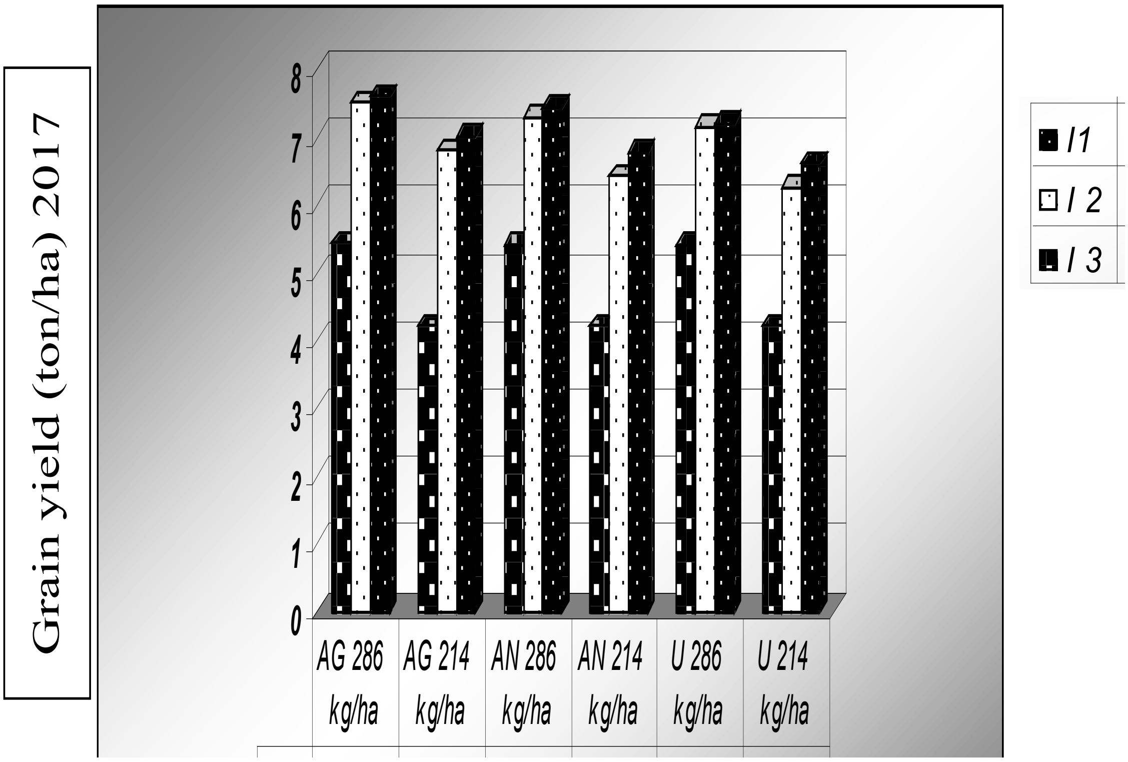
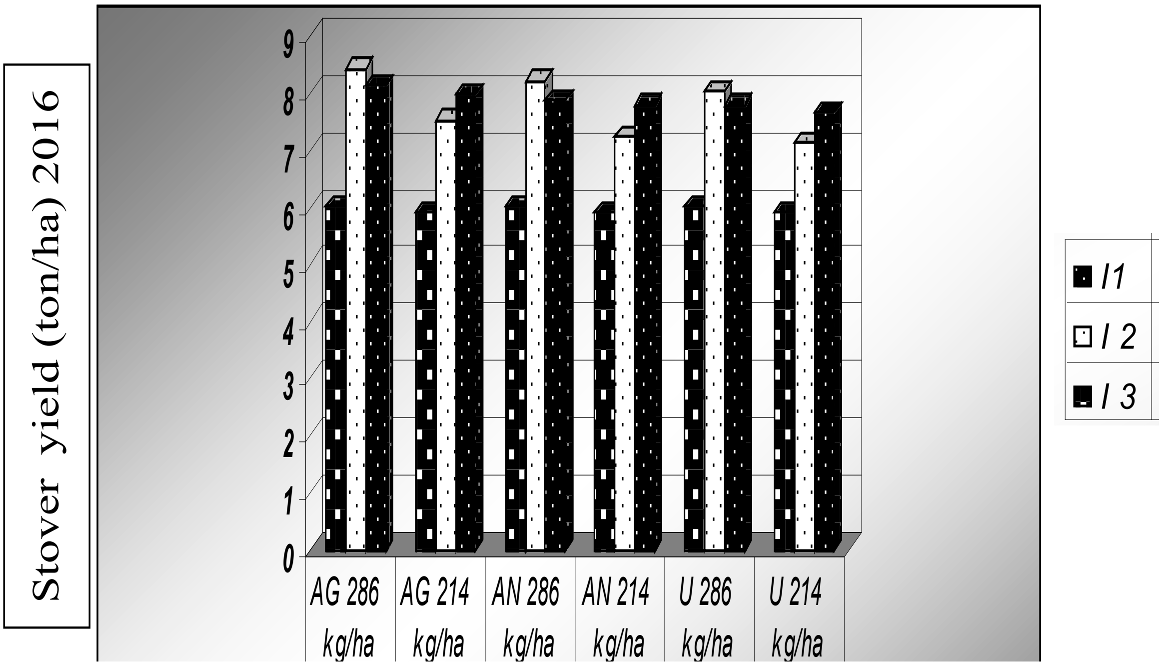


Fig. 1. Means of grain yield of maize plants as affected by irrigation schedule and nitrogen sources and levels



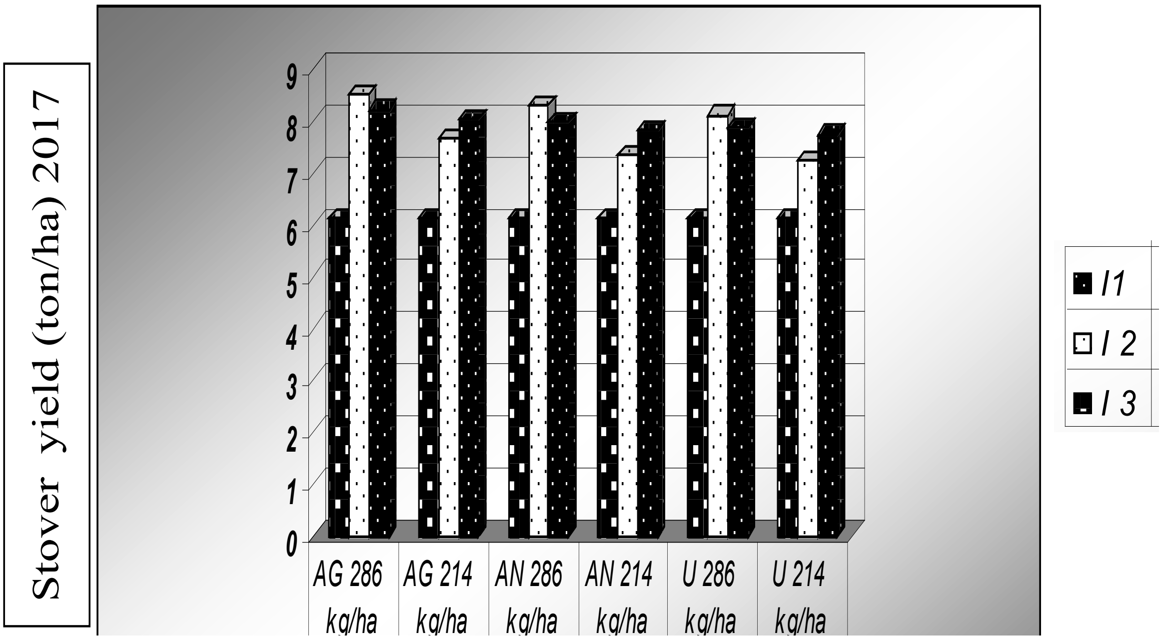


Fig. 2. Means of stover yield of maize plants as affected by irrigation schedule and nitrogen sources and levels

As for nitrogen sources, the data show that both grain and stover yields were significantly affected by nitrogen sources. The effect of nitrogen sources on grain and stover yields could be arranged in the descending order as follows: ammonia gas > ammonium nitrate > urea. The superiority of ammonia gas over ammonium nitrate and urea on maize grain yield reached 2.3 and 8.5% in the first season and 3.1 and 5.1% in the second season, respectively. Similar trends were obtained for stover yields. The superiority of ammonia gas over other two sources can be explained by the improvement in soil chemical conditions and in turn enhanced yield components of maize as discussed before. In this connection Abd El-Kader (2002) mentioned that injection of ammonia caused decreases in soil pH after 36 hours from injection. Similar results were obtained by El-Masry *et al*. (2006) and Ismail *et al*. (2014).

Regarding nitrogen levels, data in Table 6 revealed that increasing nitrogen levels up to 286 kg ha^{-1} significantly increased both grain and stover yields in both growing seasons. The application of 286 kg N ha^{-1} increased grain yield by about 15.6 and 15.2% over 214 kg N/ha in both seasons, respectively. Stover yield followed the similar pattern as grain yield. The promotive effect of increasing nitrogen levels on grain and stover yields may be due to the exuberant vegetative growth and yield components noted in the case of higher doses of nitrogen application (Shirazi *et al*., 2011). Similar results were obtained by Al-Kaisi and Yin (2003) and Markovic *et al*. (2017).

Nitrogen, P and K uptake

The data regarding nutrient uptake in grains and/or stover as affects by irrigation treatments as well as nitrogen sources and levels are given in Tables 6, 7 and 8. The increase in the available soil moisture significantly increased N, P and K in grains and/or stover. The maximum total N, P and K recorded with irrigation at 1.3 APE were 203.55, 51.60 and 182.05 kg ha^{-1} in the first season and 206.45, 52,73 and 181.23 kg ha^{-1} in the second one, respectively. Whereas, minimum total of 126.29, 30.23 and 106.48 kg N, P and K ha^{-1} in the first season and 127.34, 31.42 and 110.30 kg N, P and K in the second season, respectively were up taken by maize plants under I_3 (deficient available moisture). It can be explained that more frequent irrigation Events increase lability of nutrients, enhance nutrients diffusion as cross section area for diffusion increases and tortuosity of path is decreased (Rahim *et al*., 2010). These results are similar to those obtained by Al-Kaisi and Yin (2003) and Zorkany (2014).

Data for nitrogen sources showed that N and K uptake only were significantly affected by nitrogen sources, which ammonia gas recorded the highest values, followed by ammonium nitrate. Whereas, urea exerted the lowest N and K uptake by maize grains and/or stover. This is mainly explained by the effect of nitrogen sources on grain and stover yields, since nutrient uptake calculated as multiplying yield dry weight by nutrient concentration (see Table 1 and 2 in Appendix). These results are in line with those obtained by Ismail *et al*. (2014).

TABLE 6. Means of N, P and K uptake by maize grains as affected by irrigation and nitrogen sources and levels

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	117.72 a	118.66 a	24.43 a	24.56 a	68.25 a	70.68 a
I2 (1.0 APE)	112.22 b	114.11 b	22.27 b	22.46 b	63.96 b	66.31 b
I3 (0.7 APE)	71.18 c	71.72 c	14.19 c	14.51 c	36.51 c	37.95 c
N sources						
Urea	96.83 c	98.52 c	20.94	20.83	52.64 c	55.11 c
A. N.	100.30 b	99.99 b	20.61	20.55	56.45 b	58.33 b
A. G.	104.06 a	105.98 a	20.17	19.93	59.62 a	61.42 a
N levels						
214 kg/ha	85.01 b	92.90 b	18.81 b	20.42 b	46.57 b	49.12 b
286 kg/ha	109.62 a	110.12 a	21.70 a	21.71 a	65.97 a	67.48 a

TABLE 7. Means of N, P and K uptake by maize stover as affected by irrigation and nitrogen sources and levels

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	80.34 b	81.47 b	24.28 b	24.28 b	98.27 b	100.07 b
I2 (1.0 APE)	84.92 a	86.83 a	26.22 a	27.24 a	112.93 a	114.66 a
I3 (0.7 APE)	54.35 c	54.74 c	15.01 c	16.11 c	69.63 c	71.57 c
N sources						
Urea	69.52 c	71.46 b	21.53	22.11	90.78 c	92.58 c
A. N.	72.34 b	72.24 b	21.65	22.51	92.27 b	93.97 b
A. G.	77.75 a	79.34 a	22.38	23.00	97.67 a	99.76 a
N levels						
214 kg/ha	67.84 b	68.71 b	20.16 b	21.06 b	86.97 b	89.12 b
286 kg/ha	78.50 a	80.04 a	23.51 a	23.94 a	100.24 a	101.67 a

TABLE 8. Means of N, P and K uptake by maize plants as affected by irrigation and nitrogen sources and levels

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	198.06 a	200.13 a	48.71 a	48.78 a	166.52 b	170.86 b
I2 (1.0 APE)	197.16 a	200.94 a	48.53 a	49.70 a	176.88 a	180.98 a
I3 (0.7 APE)	126.29 b	127.34 b	30.23 b	31.54 b	106.48 c	110.30 c
N sources						
Urea	167.26 c	170.79 c	43.11	43.86	144.39 c	148.21 b
A. N.	171.59 b	173.23 b	43.18	43.92	149.64 b	148.18 b
A. G.	182.64 a	186.19 a	44.21	44.04	158.39 a	162.14 a
N levels						
214 kg/ha	159.28 b	161.96 b	39.29 b	40.70 b	133.88 b	138.53 b
286 kg/ha	188.39 a	190.40 a	46.34 a	45.95 a	166.52 a	169.81 a

Considering nitrogen levels, the data clearly show that, regardless nitrogen sources, N, P and K uptake in grains and/or stover were markedly affected by nitrogen levels. Addition of 286 kg N ha^{-1} yielded total N, P and K surpassed that due to 214 kg N ha^{-1} by about 19.0, 17.7 and 33.3%in the first season. Similar trends were obtained in the second season as well as N, P and K uptake by grains or stover in both seasons. The increment of N, P and K uptake resulted in increasing nitrogen levels may be due to the effect of nitrogen levels on grains or stover as mentioned before. Also, this increase might be attributed to the increase in root surface per soil unit volume due to nitrogen application and accordingly increased the rate of nutrients absorption (Hassanien, 2009). These results are in harmony with those obtained by Ismail *et al*. (1999) and Gebraiel *et al*. (2005).

Crop-water relations

Seasonal applied irrigation water (IW)

Data in table 9 show the amount of seasonal applied water. The data revealed that, regardless the adapted nitrogen sources and levels, watering at 1.3 of APE (I_1) resulted in higher amount of applied irrigation water found to be 8000 and 7750 m^3 ha^{-1} in both seasons, respectively. On the other hand, watering at 1.0 (I_2) and 0.7 (I_3) of APE found to be 7010 and 6110 in the first season, and 6820 and 5920 m^3 ha^{-1} in the second one, respectively. The applied water (IW) at 0.7, 1.0 and 1.3 of A.P.E. were distributed through 5, 6 and 7 irrigation events including sowing and first irrigation in both seasons. The reduction in seasonal applied water due to decrease in the A.P.E. is mainly attributed to the decrease of irrigation events. It is worthy to notice that, seasonal applied irrigation water did not respond to both nitrogen sources or levels. These results agree with those results obtained by El-Bably (2007), Eid *et al*. (2010) and Zorkany (2014).

TABLE 9. Means of seasonal applied water, seasonal consumptive use, water utilization efficiency and water use efficiency as affected by irrigation treatments and nitrogen sources and levels

Treatments	Seasonal applied water (m^3 ha^{-1})		Seasonal consumptive use (m^3 ha^{-1})		Water utilization efficiency (kg m^{-3})		Water use efficiency (kg m^{-3})	
	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation								
I1 (1.3 APE)	8000 a	7750 a	6927 a	7084 b	0.88 b	0.92 b	1.02 b	1.01 b
I2 (1.0 APE)	7010 b	6820 b	6937 a	7150 a	0.98 a	1.02 a	0.99 c	0.95 c
I3 (0.7 APE)	6110 c	5920 c	4886 b	4585 c	0.78 c	0.82 c	1.08 a	1.05 a
N sources								
Urea	7040	6830	5823 c	6038 c	0.86 c	0.90 c	1.05 a	1.03 a
A. N.	7040	6830	6077 b	6235 b	0.88 b	0.92 b	1.03 b	1.01 b
A. G.	7040	6830	6349 a	6546 a	0.90 a	0.94 a	1.01 c	0.99 c
N levels								
214 kg/ha	7040	6830	5564 b	5758 b	0.81 b	0.85 b	1.04 a	1.02 a
286 kg/ha	7040	6830	6602 a	6787 a	0.94 a	0.99 a	1.01 b	0.99 b

Seasonal consumptive use (CU)

Mean values of seasonal consumptive use as affected by irrigation and nitrogen treatments for maize are presented in Table 9. Plants irrigated through 1.3 of A.P.E (I_1) was accompanied with the highest seasonal consumptive use with an amount of 6927 and 7084 m^3 ha^{-1} in both seasons, respectively, followed by I_2 with6937 and 7150 m^3 ha^{-1} in both seasons, respectively. Whereas, I_3 treatment exhibited the lowest seasonal consumptive use (4886 and 4585 $m^3 ha^{-1}$ in the two studied seasons, respectively). These results indicated that water consumptive use increased as soil moisture was maintained high by frequent irrigation. Also, it could be explained by higher frequent of irrigations provide chance for more consumption of water ultimately resulted in increasing transpiration and evaporation from the soil surface (Eid et al, 2010). Similar results were obtained by El-Tantawy *et al*. (2007).

Water utilization efficiency (WUtE, kg m-3)

Water utilization efficiency or productivity of maize grains (kg m^{-3}) obtained from each cubic meter of water consumed as affected by irrigation scheduling, nitrogen sources and nitrogen levels is presented in Table 9. Results indicate that the highest values of WUtE were obtained under the irrigation at 1.0 of A.P.E (I_2), followed by irrigation at 1.3 of A.P.E (I_1). Whereas the irrigation at 0.7 of A.P.E (I_3) exhibited the lowest WUtE. These results could be attributed to the higher grain yield under I_2 treatment comparable to I_1 and I_3 treatments. Similar results were obtained by Hegab *et al*. (2014) and Ewis *et al*. (2015).

As for nitrogen sources, the results showed that water utilization efficiency was significantly affected by nitrogen sources. The effect of the studied nitrogen sources on WUtE could be arranged in the descending order as follow: ammonia gas > ammonium nitrate > urea fertilizer. These results could be explained by the effect of these fertilizers on maize grain yield, since seasonal applied water was constant for each fertilizer sources.

Considering nitrogen levels, the data clearly showed that increasing nitrogen level from 214 to 286 kg ha^{-1} had a positive effect on water utilization efficiency in both seasons, which mainly due to the increment of grain yield with increasing nitrogen level. The relative increasing of water utilization efficiency due to 286 kg N ha^{-1} reached to 16.0 and 16.5% over 214 kg N ha^{-1} in both seasons, respectively. These results agree with those obtained by Eid *et al*. (2010) and Ewis *et al*. (2016).

Water use efficiency (WUE, kg m-3)

Water use efficiency (WUE) is a parameter which indicates the capability of plants to utilize the soil moisture stored in the effective root zone. The water use efficiency as affected by irrigation scheduling and nitrogen sources and levels are shown in Table (9). The results revealed that irrigation at 0.7 of A.P.E. (I_3) gave the highest values of WUE (1.08 and 1.05 kg grains m^{-3} in both seasons, respectively), followed by irrigation at 1.3 of A.P.E. (1.02 and 1.01 kg maize grains m^{-3} in the two seasons. On the other hand, irrigation at 1.0 of A.P.E. produced the lowest water use efficiency (0.94 and 0.95 kg grains m^{-3} in both seasons, respectively). The superiority of the effect of I_3 treatment is mainly due to the reduction in seasonal applied water. However, the reduction in WUE under I_2 treatment is attributed to the higher water availability which can reduce the amount and efficiency of water (Maman *et al*. 2003). In this regard Ehdaie *et al*. (1991) and Ebdon *et al*. (1998) who mentioned that the amount of water used and water use efficiency vary with climatic, soil conditions and the ability of the crops to extract water stored in soil. These results are in line with those obtained by Zorkany (2014).

As for nitrogen sources, the data indicated that water use efficiency was significantly responded to nitrogen sources. The effect of nitrogen sources on water use efficiency could be arranged in the descending order as follow: urea> ammonium nitrate > ammonia gas. These results may be due to the effect of different nitrogen fertilizers on seasonal consumptive use (Ewis *et al*., 2016). Regarding nitrogen level, the data revealed that increasing nitrogen level from 214 to 286 kg ha^{-1} positively decreased water use efficiency. These results are mainly explained by the effect of nitrogen on improving the growth of roots and shoots of maize, consequently improved water absorption (Ewis *et al*., 2016). These results coincided with those obtained by Yang *et al*. (2005), El-Atawy (2007) and Eid *et al.* (2010).

Conclusion

The results of this investigation showed that the highest grain and stover yields of maize plants were obtained when plants were irrigated using 1.0 or 1.3 pan evaporation coefficient with no significant differences between them. However, the highest water productivity was obtained under irrigation with 1.0 pan evaporation coefficient which means that the possibility to save about 960 m^3 ha^{-1} from the applied irrigation water with slightly insignificant reduction in maize yields. Therefore, it is recommended to apply irrigation water using 1.0 of A.P.E. and fertilized maize plants with anhydrous ammonia at the rate of 286 kg N ha^{-1} to maximize maize production and save irrigation water.

Appendix

TABLE 1. Means of N, P and K concentration in maize grains plants as affected by irrigation and nitrogen sources and levels

Treatments	N%		P%		K%	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	1.65 a	1.66 a	0.33 a	0.34 a	0.98 a	0.97 a
I2 (1.0 APE)	1.64 a	1.65 a	0.33 a	0.33 a	0.88 a	0.89 a
I3 (0.7 APE)	1.48 b	1.48 b	0.28 b	0.28 b	0.75 b	0.76 a
N sources						
Urea	1.58 b	1.59 b	0.31	0.32	0.84 b	0.86 b
A. N.	1.59 b	1.58 b	0.32	0.32	0.84 b	0.86 b
A. G.	1.61 a	1.62 a	0.32	0.32	0.90 a	0.91 a
N levels						
214 kg/ha	1.56 b	1.56 b	0.31	0.31	0.77 b	0.79 b
286 kg/ha	1.62 a	1.62 a	0.31	0.31	0.94 a	0.96 a

TABLE 2. Means of N, P and K concentration in maize stover plants as affected by irrigation and nitrogen sources and levels

Treatments	N%		P%		K%	
	2016	2017	2016	2017	2016	2017
Irrigation						
I1 (1.3 APE)	1.08 a	1.09 a	0.33 a	0.34 a	1.44 a	1.45 a
I2 (1.0 APE)	1.01 a	1.00 a	0.30 b	0.30 b	1.24 b	1.25 b
I3 (0.7 APE)	0.87 a	0.88 a	0.24 c	0.25 c	1.15 b	1.15 b
N sources						
Urea	0.96 b	0.96 b	0.29	0.30	1.26 b	1.28 b
A. N.	0.96 b	0.98 b	0.29	0.30	1.26 b	1.27 b
A. G.	1.03 a	1.04 a	0.29	0.29	1.35 a	1.31 a
N levels						
214 kg/ha	0.93 b	0.93 b	0.27	0.28	1.22 b	1.23 b
286 kg/ha	1.04 a	1.05 a	0.30	0.30	1.33 a	1.33 a

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جدوله الرى ومصادر ومستويات مختلفة للنيتروجين لانتاجية محصول الذرة الشامية وبعض العلاقات المائية

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أجريت هذة الدراسة بمزرعة محطة البحوث الزراعية بسدس- محافظة بنى سويف – مصر خلال موسمى النمو ٢٠١٦ ، ٢٠١٧ لدراسة تأثير جدولة الرى بأستخدام وعاء البخر القياسى تحت مصادر ومستويات مختلفة من النيتروجين على انتاجية محصول الذرة وبعض العلاقات المائية. استخدم تصميم القطع المنشقة مرتان فى أربع مكررات، وقد خصصت القطع الرئيسية لمعاملات جدولة الرى وهى الرى عند٠,٧ - ١,٠ – ١,٣ من البخر التراكمى لوعاء البخر القياسى، فى حين وزعت مصادر النيتروجين (الحقن بالأمونيا الغازية، وسماد نترات الأمونيوم، سماد اليوريا) على القطع المنشقة، كما أضيفت معدلات التسميد النيتروجينى (٢١٤، ٢٨٦ كجم نيتروجين/هكتار) فى القطع المنشقة المنشقة. وعند الحصاد قدرت مكونات المحصول (عدد الصفوف فى الكوز، عدد الحبوب فى الصف، وزن المائة حبة) ومحصول الحبوب والقش. كما قدر امتصاص النيتروجين والفوسفور والبوتاسيوم فى الحبوب والقش وكذلك بعض العلاقات المائية (كمية المياه الكلية المضافة، الاستهلاك المائى، كفاءة الاستفادة من مياة الرى، كفاءة استخدام مياة الرى). وقد أوضحت النتائج ما يلى:-

- أدى الرى عند ١,٠ أو ١,٣ من البخر التراكمى لوعاء البخر القياسى الى زيادة معنوية فى مكونات المحصول ومحصول الحبوب والقش وامتصاص عناصر النيتروجين والفوسفور والبوتاسيوم والكمية الكلية للمياه المضافة والاستهلاك , ما عدا عدد الحبوب فى الصف الذى لم يتأثر بجدولة الرى. وكان الفرق تأثير الرى عند ١,٣ و١,٠ من البخر التراكمى لوعاء للبخر القياسى على محصول الحبوب والقش غير معنوى.

- أدى الرى عند ١,٠ من البخر التراكمى لوعاء البخر القياسى الى أعلى قيم لكفاءة الاستهلاك واستخدام مياة الرى، بينما أدى الرى عند ٠,٧ من البخر التراكمى لوعاء البخر القياسى الى أقل القيم.

- أدى تسميد الذرة الشامية بالأمونيا الغازية الى أعلى قيم للمحصول ومكوناته وأمتصاص العناصر والاستهلاك الموسمى لمياة الرى وكفاءة الاستفادة واستخدام مياة الرى، يليها التسميد بسماد نترات الأمونيوم، بينما أدى التسميد باليوريا الى اقل القيم، ما عدا عدد الحبوب فى الصف التى لم تتأثر.

- أدى زيادة التسميد النيتروجينى الى ٢٨٦ كجم نيتروجين/هكتار الى تحسن كل صفات المحصول ومكوناته وأمتصاص العناصر والعلاقات المائية ما عدا كمية المياة الكلية المضافة التى لم تتأثر بمستويات التسميد النيتروجينى.

- من نتائج الدراسة يمكن التوصية برى الذرة الشامية عند معامل البخر ١,٠ والتسميد النيتروجينى بمعدل ٢٨٦ كجم/هكتار على صورة حقن بالأمونيا للحصول على أعلى انتاجية لمحصول الذرة مع توفير حوالى ٩٦٠ م^3 لكل هكتار مع عدم حدوث انخفاض معنوى فى المحصول.