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RESPONSE OF SUNFLOWER YIELD AND CROP -WATER RELATIONS TO LIQUID AMMONIA FERTILIZATION LEVELS AND IRRIGATION WATER QUANTITIES

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ABSTRACT

Two field trials were conducted at Tamiea Agric. Res. Station, Fayoum Governorate, Egypt during 2012 and 2013 summer seasons to investigate the effect of three N fertilization rates, i.e. N_1 : 40, N_2: 50, and N_3: 60 kg/fed as liquid ammonia (one kg of liquid ammonia contains 82.5% N) combined with three levels of irrigation water quantities e.g. 2200, 2500 and 2800 m^3/fed distributed during the growing season onto six irrigation events. The adopted treatments were assessed in a strip-plot design with four replications on yield components, yield and some crop water relations. The main results obtained were as follows:

- Seed yield and yield components were significantly affected due to N fertilization levels and applied irrigation water quantities in 1^{st} and 2nd seasons.
- The highest averages of plant height, head diameter and weight, seed weight/head, 100-seed weight and seed yields (792.15 and 816.49N kg/fed in 2012 and 2013 seasons, respectively), were detected from injecting the soil with liquid ammonia as 60 kgNfed^{-1} level and irrigating with 2800 m^3 water/fed whereas the lowest yield components, and seed yield (565.61 and 580.52 kg/fed) were obtained with 40 kgNfed^{-1} level and applying 2200 m^3 water/fed.
- The highest seed oil content i.e. 42.23 and 42.31 % in 2012 and 2013 seasons, respectively. were obtained due to 40 kgNfed^{-1} level.and 2800 m^3 water /fed rate interaction.
- Seasonal evapotranspiration (ET_C) was maximum (50.76 and 51.77 cm in 2012 and 2013) with applying 60 kgNfed^{-1} level and irrigating at 2800 m^3/fed water interaction. The monthly crop coefficients (K_C) under the highest yielding interaction were 0.57, 0.76, 0.95 and 0.62 for July, August, September and October, respectively, (means of the two seasons).

Applying 50 kgN fed^{-1} level and irrigating with 2200 m^3/ fed rate is the most efficient interaction for water use with values comprised 0.374 and 0.382 kg seeds/ water consumed in 2012 and 2013 seasons, respectively. Moreover, the highest water productivity (WP) values i.e. 0.321 kg seeds/m^3 water applied, respectively, in 2012 and 2013 seasons were recorded due to 60 Nkg fed^{-1} level and 2200 m^3/fed water interaction.

Keywords: sunflower, liquid ammonia fertilization, yield, yield components, ET crop, $K_{C,}$ water use and water utilization efficiencies.

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INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops around the world.In Egypt, great attention must be given towards this crop to decrease the gap in crop oil production. Increasing the crop production per unit area is a very important concern and this can be achieved through improving the agricultural practices i.e. high yielding varieties, efficient irrigation and fertilization management, …., etc. Optimizing nitrogen fertilization is an important factor at different soil types and environments. Liquid ammonia fertilization is a new technology used nowadays due to lower costs as well as its favorite influence on decreasing soil salinity caused by mineral fertilizers. Irrigation management, particularly under limited water resources, also play an important role in enhancing water utilization and crop production. Karami(1980) found that plant height, yield components and seed yield for sunflower were increased by applying 50 kg $Nfed^{-1}$, while higher N rates produced no additional increases in yield and its components. In addition, seed oil content was decreased with increasing N rates. Mohammed and Rao (1981) reported that oil content slightly increased with 40 kg N/ ha, but decreased with 80 – 120 kg N/ha. El Sayed *et al.* (1984) and Triathi and Sawhney (1989) found that plant height, stem diameter, all yield components and seed yield for sunflower were significantly increased due to increasing N levels to 50 kg /fed, whereas seed oil content was decreased. Ashry *et al.* (2013) found that applying 60 kg ammonia gas, as N fertilization gave the highest sunflower yield component and seed yield, whereas seed oil content and tended to decrease.The authors added that seasonal ET_C and water use efficiency were increased as ammonia gas fertilization level increased.

Regarding the effect of irrigation on yield, yield components and the crop water relations, Doorenbos *et al.* (1979) indicated that the water requirements for sunflower are vary from 60 to 100 cm depending on climate and growing season length, and higher evapotranspiration (ET_C) rates (12-15 mm/day) occurred during seed setting period. The authors added that the crop coefficient (K_C) is 0.3 – 0.4; 0.7 – 0.8; 1.05 – 1.20; 0.7 – 0.8 and 0.4 for the initial stage (20 -25 days), the crop establishment (35 – 40 days), the mid-season (40 – 50 days), the late season (25 – 30 days) and at maturity or harvest, respectively. El-wakil and Gaafar (1986) showed that increasing available soil moisture depletion (ASMD) from 40 to 60 and 80% caused significant decrease in head diameter, seed yield and seed oil content. and. Also, ET_C values decreased from 1492 to 1215.5 and 1084 m^3 water, whereas, irrigation at 60% ASMD gave the highest WUE (1.24 kg seed/m3 water consumed) .Attia *et al.* (1990) concluded that irrigation at 75% ASMD significantly decreased plant height, head diameter and weight, seed weight/plant, 100- seed weight and seed yield/fed by 37.2%, 41.1%, 46.5%, 40.6%, 4.1%, 43.5%, respectively, compared to irrigation at 25%ASMD. They added that ET_C was increased from 1611.5 to 1748.5 and 1824.1 m^3/fed, as the ASMD decreased from 75% to 50% and 25%, respectively. Kumar et al. (1991) pointed out that seed oil content increased with increasing soil moisture. Green and Read (1993) found that sunflower was very responsive to soil moisture stress, where decreasing ASM decreased dry matter production/ m^3 water consumed. However, ET_C increased from 12.4 to 34.11 cm, as the soil moisture increased from slightly above the wilting point to the field capacity. Sharma (1994) indicated that increasing number of irrigations from one to three increased head diameter and seed yield, while 100-seed weight did not affect. Abdou *et al* (2011) reported that irrigation at short interval 1.2 cumulative pan evaporation (C.P.E) gave the highest yield component, seed yield, seasonal and daily ET_cvalues and WUE. The author added that crop coefficient (K_C) values were 0.44, 0.73, 0.98 and 0.63 for June, July, August and September, respectively. Ashry *et al.* (2013) found that irrigation at 1.2 (C.P.E.) gave the highest averages of yield components, seed yield (881.74 kg/fed), seed oil content (41.48%), ET_C (49.64 cm), daily ET_C/ month, WUE (0.420 kg seeds/m^3 water consumed) when compared with irrigation at 0.6 or 0.8 (C.P.E.). The K_C values were 0.42, 0.55, 0.63, 0.89 and 0.51 in May, June, July, August and September, respectively.

The present research trial aiming at finding the response of sunflower seed yield, cropwater use and water use efficiency to N fertilization levels, as liqiuid ammonia, and applied irrigation water quantities at Fayoum district. Crop coefficient, yield components and water productivity were also considered.

MATERIALS AND METHODS

Two field experiments were conducted at Tameia Res. Station, Fayoum Governorate during 2012 and 2013 seasons. This investigation aims to study the effect of applied water quantities and nitrogen fertilization levels on sunflower seed yield, yield components and some crop - water relations. Three N fertilization levels, i.e. 40, 50 and 60 kg Nfed^{-1} as liquid ammonia (one kg of liquid ammonia contains 82.5% N) were combined with three irrigation water quantities e.g. 2200, 2500 and 2800 m^3fad^{-1} season namely lower, medium and higher irrigation levels, respectively. The adopted treatments were assessed in a strip plot design with four replicates. The plot area was 21.0 m^2 (3.5 x 6.0m) and contained six ridges of 60 cm width and 6.0 m length. Sunflower seeds (Sakha 53 hybrid) were sown at 5.0 kgfed^{-1} rate in hills 20 cm apart system. Sowing dates were July 5th and July12th in 2012 and 2013 seasons, whereas, harvesting was xexcuted on October 10th and October 17th in the two seasons, respectively.All of the recommended agricultural practices for sunflower production were done.The tested nitrogen fertilization levels (as liquid ammonia) were injected before ridging. Each plot was isolated from the others by allays 2.0 m in between to avoid the lateral water movement . Data in Table (1) show soil particle size distribution and some chemical soil properties as determined according to Klute (1986) and Page *et al.* (1982). The weather factors of Fayoum Governorate during the sunflower growing seasons are presented in Table (2). Some soil moisture constants are are recorded in Table (3). Except planting irrigation, the applied water quantity in each irrigation event was estimated as percentage of the predetermined seasonal water quantity based on the monthly crop coefficient values of sunflower crop grown at the region and stated by Abdou *et al* (2011). The total seasonal water quantity were distributed on six irrigations after the planting one. The applied water was measured using a water meter attached to the water pump. The proceeding crop was wheat in both seasons. At harvesting time the following data were recorded for each plot.

1-**Yield and yield components**

- Seed yield (kg fed^{-1}) -Plant height (cm) - Head diameter (cm)
- Head weight (g) -Seed weight/ head (g) -100- seed weight (g).
- Seed oil content (%).

11- Crop - water relations

1-Seasonal consumptive use (ETc)

To determine crop evapotranspiration (ETc), soil samples were taken from each sub-plot, just before and 48 hours after irrigation, as well as at harvesting time. The ETc between each two successive irrigations was calculated according to Israelsen and Hansen, 1962.

$$Cu\ (ET_C) = \{(Q_2 - Q_1) / 100\} \times Bd \times D$$ where :

Cu = crop water evapotranspiration (cm)

Q_2 = soil moisture percentage (wt wt^{-1})

Q_1= Soil moisture percentage (wt wt^{-1}) just before irrigation .

Bd = Soil bulk density (gm cm^{-3}). and D = Soil layer depth (cm).

2-**Daily ET_C rate (mm day^{-1})**

Calculated from the ET_C between each two successive irrigations divided by the number of days .

3-**Reference evapotranspiration (ET_0) in mm/ day .**

Reference evapotranspiration (ET_0) was estimated using the monthly averages of Fayoum climatic data (Table. 2) and the FAO Penman- Monteith equation. **(Allen et al., 1998).**

4-**Crop coefficient (Kc).**

The values of Kc were calculated as follows:

$$K_C = ET_C / ET_0 \quad \ldots\ \ldots\ \ldots\ \ldots$$ Where

ET_C = Actual crop evapotranspiration (mm day^{-1})

ET_0 = Reference evapotranspiration (mm day^{-1})

5-Water use efficiency (WUE) and Water productivity (WP)

Water use efficiency **(**WUE) as kg seeds/ m^3 of water consumed and Water productivity (WP) were calculated according to Doorebose and Pruit (1975) as follows:-

$$WUE,\ kg\ m^{-3} = \text{Seed yield (kg fed}^{-1}) / \text{Seasonal } ET_C\ (m^3 fed^{-1})$$

Water productivity (WP)or water utilization efficiency(WUtE), kgm^{-3} =

$$\text{Seed yield (kg fed}^{-1}) / \text{applied irrigation water } (m^3 fed^{-1})$$

Table 1. Particle size distribution and some chemical soil analyses of the experimental site at 2012 and 2013 seasons (average of two seasons)

Particle size distribution								Organic matter (%)			CaCo$_3$ (%)			
Sand %		Silt %		Clay %		Textural class								
38.00		21.20		40.80		Clay loam		1.68			5.18			
Soluble cations ($meqL^{-1}$)				Soluble anions ($meqL^{-1}$)				EC (dSm^{-1})	p^H	CEC (meq/100g soil)	Exchangeable cations (meq/100g soil)			
Ca^{+2}	Mg^{+2}	Na^+	K^+	Cl^-	HCO_3^-	CO_3^{-2}	SO_4^{-2}				Ca^{+2}	Mg^{+2}	Na^+	K^+
8.18	7.69	24.67	0.33	20.73	3.06	-	17.08	4.00	8.12	32.47	16.43	10.47	4.15	1.41

Table (2): Monthly averages of weather factors for Fayoum Governorate during 2012 and 2013 seasons

Month	season	Temperature C°			Relative Humidity%	Wind Speed ($msec^{-1}$)	Class A pan evaporation ($mmday^{-1}$)
		Max.	Min.	Mean			
July	2012	39.8	23.9	30.9	47	1.88	7.5
	2013	37.1	24.6	30.9	46	1.74	7.4
August	2012	38.0	25.2	31.6	50	2.01	6.8
	2013	38.1	24.9	31.5	44	2.10	6.5
September	2012	35.2	23.4	29.3	49	2.24	5.5
	2013	36.6	23.6	30.1	44	2.17	5.8
October	2012	34.4	22.2	28.3	49	2.01	4.1
	2013	30.8	19.5	25.1	43	2.15	4.2

Table(3):Average values of soil moisture constants for the experimental field during 2012 and 2013 seasons(average of the two seasons)

Soil depth (cm)	Field capacity (%,wt/wt)	Wilting point (%,wt/wt)	Bulk density (gcm^{-3})	Available moisture (%,wt/wt)
0-15	41.99	20.19	1.40	21.80
15-30	39.89	19.10	1.41	20.79
30-45	35.91	16.35	1.37	19.56
45-60	34.21	16.71	1.36	17.50

Table(4):Date and applied water quantity under different irrigation levels

Irrigation event	2012				2013			
	Irrigation date	Lower level	Medium level	Higher level	Irrigation date	Lower level	Medium level	Higher level
planting	5/7	**400**	**400**	**400**	**12/7**	**400**	**400**	**400**
1st irrigation	20/7	250	300	350	27/7	250	300	350
2nd irrigation	5/8	300	350	400	11/8	300	350	400
3rd irrigation	17/8	350	400	450	23/8	350	400	450
4th irrigation	29/8	350	400	450	4/9	350	400	450
5th irrigation	10/9	350	350	400	19/9	350	350	400
6th irrigation	25/9	200	300	350	3/10	200	300	350
Total		2200	2500	2800		2200	2500	2800
Harvesting	10/10/2012				17/10/2013			

The collected data concering seed yield and yield components were subjected to the statistical analysis as outlined by Snedecor and Cochran (1980) and the means of the treatments were compared at the level of 0.05 significance.

RESULTS AND DISCUSSION

I. Seed Yield and yield components

The results in Table (5) reveal that, except seed oil content% character, seed yield and yield components attributes were significantly affected due to both adopted N fertilization rates and irrigation water levels in the two seasons of study. The highest values of seed yield (731.64 and 762.70 kgfed^{-1}) were obtained from injecting soil with 60 kgNfed^{-1} in 2012 and 2013 seasons, respectively. Reducing N rate to be 50 or 40 kgNfed^{-1} resulted in lower seed yield values amounted to 5.27 and 15.65% in 1st season and to 4.41 and 15.63% in 2nd season, respectively, comparable to 60 kgNfed^{-1} rate. Furthermore, the obtained values for the yield components e.g. plant height, head diameter, head weight, seed weight/head and 100-seed weight exhibited the same trend, where the highest figures were recorded under 60 kgNfed^{-1} rate and seemed to be lower under 50 or 40 kgNfed^{-1} and such findings were true in 1st and 2nd seasons. These results may be referred to the role of nitrogen in stimulating amino acids building and growth hormones, which in turn gave positive effect on cell division and translocation of metabolites to the plant head and seeds. In addition, seed oil content% character adversely responded to the assessed N rates, where the value tended to reduce as N rate increased and such trend was true in the two seasons of study. Such finding could be attributed to higher N absorption, under higher N rate, which disturped C/N ratio during the fatty acids formation in the seeds. The obtained results are in agreement with those reported by Karami (1980), Mohammed and Rao (1981), El. Sayed *et al.* (1984) and Tripathi and Sawhney (1989.

Regarding the effect of irrigation levels, data in Table (5) indicate that sunflower seed yield and yield components and seed oil content as well were significantly increased as irrigation level and such findings were true in 1st and 2nd seasons. The highest seed yield values were recorded under 2800 m^{3}fed^{-1} level and comprised 735.54 and 766.98 kgfed^{-1}in 1st and 2nd seasons, respectively. Seed yield tended to reduction under 2200 and 2500 m^{3}fed-1 levels to be 7.18 and 14.45% in1st season and 8.58 and 13.15% in 2nd one, respectively, lower than those under 2800 m^{3}fed$^-$1 level. In addition, values for the yield components e.g. plant height, head diameter, head weight, seed weight/head and 100-seed weight as well as seed oil content revealed similar trend, where the highest figures were recorded with 2800 m^{3}fed^{-1} level and seemed to be lower under 2500or 2200 m^{3}fed^{-1} and such findings were true in 1st and 2nd seasons. These results may be attributed to the proper available soil moisture in the root zone of plants during the growing season resulted from increasing irrigation water level, which in turn increased photosynthesis, net assimilation rate, cell division, stem elongation and dry matter accumulation in al plant organs, especially during anthises and seed filling stages. These results were previously confirmed by El-Wakil and Gaafar (1990), Kumar *et al.* (1991), Green and Riad (1993), Sharma (1994), Abdou *et al.* (2011) and Ashry *et al.* (2013).

With respect to the interaction effect of N levels and irrigation water rates, results in Table (5) show that, although the interaction exerted a different significant effects to alter some of yield components traits, it is obvious that 60 kg Nfed^{-1} rate as interacted with irrigation rate of 2800 m^{3}fed^{-1} resulted in higher figures for the measured seed yield and yield components in the two seasons of study.

Table 5:Effect of N fertilization level, irrigation water quantity and their interaction on sunflower yield and its components in 2012 and 2013 seasons

N rate (Kgfed^{-1})	Irrigation level (m^{3}fed^{-1})	Plant height (cm)	Head diameter (cm)	Head Weight (g)	Seed weight/head (g)	100-seed weight (g)	Seed yield (kgfed^{-1})	Seed oil content (%)
2012 season								
40	2200	132.4	13.99	199.34	96.81	6.31	565.61	40.65
	2500	140.6	15.86	211.62	99.32	6.89	603.40	41.22
	2800	149.9	17.47	219.93	105.20	7.12	682.33	42.23
Mean		141.0	15.77	210.30	100.44	6.77	617.11	41.37
50	2200	142.8	15.08	210.50	101.50	6.92	655.60	39.25
	2500	152.7	16.61	221.60	104.21	7.23	691.46	40.16
	2800	159.4	17.74	230.48	109.40	7.68	732.15	40.95
Mean		151.6	16.48	220.86	105.04	7.28	693.07	40.12
60	2200	153.6	15.91	220.91	105.10	7.37	680.26	38.65
	2500	161.2	17.08	231.12	108.23	7.74	722.50	39.21
	2800	165.8	18.14	242.10	113.31	8.05	792.15	40.06
Mean		160.2	17.04	231.38	108.88	7.72	731.64	39.41
Irrigation mean								
2200		142.9	14.99	210.25	101.14	6.87	633.82	39.52
2500		151.5	16.52	221.45	103.92	7.29	672.45	40.20
2800		158.4	17.78	230.84	109.30	7.62	735.54	41.08
LSD, 05								
Nitrogen levels (N)		1.64	0.18	1.98	2.37	0.27	4.04	1.06
Irrigation levels (I)		0.88	0.24	0.16	0.88	0.16	2.22	0.68
N x I		1.53	0.42	N.S	N.S	N.S	3.83	N.S
2013 season								
40	2200	134.9	14.58	205.39	97.92	6.45	580.52	40.76
	2500	142.5	16.16	217.25	103.75	6.95	648.75	41.33
	2800	153.2	17.95	230.29	109.63	7.19	701.15	42.31
Mean		143.5	16.23	217.64	103.77	6.86	643.47	41.47
50	2200	141.2	16.02	218.5	107.25	7.06	682.19	39.38
	2500	151.6	17.10	236.62	109.64	7.47	721.72	40.30
	2800	162.1	18.06	249.71	114.83	7.94	783.29	41.10
Mean		151.6	17.06	234.96	110.57	7.49	729.07	39.25
60	2200	155.4	16.91	229.5	110.00	7.58	706.29	38.28
	2500	163.7	17.72	246.1	113.59	7.82	765.32	39.21
	2800	168.6	18.65	264.36	117.92	8.19	816.49	40.25
Mean		162.6	17.76	246.65	113.84	7.86	762.70	39.25
Irrigation level mean								
2200(m^{3}fed$^{-1)}$		143.8	15.84	217.82	105.06	7.03	656.33	39.47
2500(m^{3}fed$^{-1)}$		152.6	16.99	233.32	108.99	7.41	711.93	40.28
2800(m^{3}fed$^{-1)}$		161.3	18.22	248.12	114.13	7.77	766.98	41.22
LSD, 05								
Nitrogen levels (N)		1.99	0.54	2.66	0.94	0.26	1.91	0.82
Irrigation levels (I)		2.18	0.49	1.13	0.60	0.14	1.05	0.39
N x I		1.12	N.S	1.96	1.03	N.S	1.81	N.S

II. Crop water relations

I - Seasonal evapotranspiration (ET_C)

Data in Table (6) indicate that seasonal ET_C of sunflower, as a function of N fertilization levels and irrigation rates were 44.68 and 45.39 cm in 2012 and 2013 seasons, respectively. The seasonal ET_C values were increased as N fertilization level increased where the increases in ET_C under 60 kgNfed^{-1}

rate were 7.32 and 13.51% in 1st season and 7.20 and 14.72% in 2nd one comparing with 50 and 40 kgNfed^{-1} rates, respectively. These results may attributed to the higher transpiration resulted from higher both seed yield and vegetative growth under higher N fertilization level. These results are in agreement with those reported by Ashry *et al.* (2013).

Regarding the effect of irrigation water levels on seasonal ET_C, data show that the highest ET_C values, i.e. 47.33 and 48.10 cm in 2012 and 2013 seasons, respectively, were recorded with the highest irrigation rate 2800 m^3 fed^{-1}. Reducing the irrigation water level to be 2500 or 2200 m^3fed^{-1} resulted in lower ET_C figures amoumted to 5.44 and 13.20% in 1st season and 5.51 and 13.26% in 2nd one, respectively, comparable with 2800 m^3 fed^{-1} level. These results are referred to that less applied irrigation water during the season which caused a decrease in the available soil moisture in the crop root zone as well as both evaporation from the soil surface and the transpiration from the crop canopy. These results are in accordance with those reported by El-Wakil and Gaafar (1986), Attia *et al.* (1990), Green and Read (1993), Abdou *et al.* (2011) and Ashry *et al.* (2013).

Data in Table (6) indicate that the highest ET_C values.e.g. 50.76 and 51.77 cm in 2012 and 2013 seasons, respectively, were obtained due to the interaction of 2800 m^3fed^{-1} rate and 60 kgN fed^{-1} level as liquid ammonia fertilization. On the contrary, 2200 m^3fed^{-1} rate as interacted with 40 kgN fed^{-1} level resulted in the lowest ET_C values (39.02 and 39.34 cm in 1st and 2nd seasons, respectively).

Table (6). Effect of N fertilization level, irrigation quantity and their interaction on seasonal evapotranspiration (ET_C) of sunflower in 2012 and 2013 seasons

N fertilization level (kg fed^{-1})	**2012**			**Mean**	**2013**			**Mean**
	Irrigation level (m^3fed^{-1})				**Irrigation level(m^3fed^{-1})**			
	2200	2500	2800		2200	2500	2800	
40	39.02	42.62	44.30	41.98	39.34	42.97	44.66	42.32
50	41.70	44.57	46.92	44.40	42.54	45.46	47.86	45.29
60	44.72	47.48	50.76	47.65	45.53	48.34	51.77	48.55
Mean	41.81	44.89	47.33	44.68	42.47	45.59	48.10	45.39

6- **Daily ET_C rate (mmday^{-1})**

The daily ET_C rates were calculated from the ET_C between each two successive irrigations and divided by the number of days between the two successive irrigations from planting to preharvesting, Table (7). It is clear that the daily ETc rate was increased by increasing N fertilization level from 40 to 50 or 60 kg Nfed^{-1}. In addition, the highest irrigation rate (2800 m^3/fed water) resulted in the highest daily ET_C rate at every irrigation. Daily ET_C rates for the highest yielding interaction i.e. applying 60 kgNfed^{-1} , as liquid ammonia, and irrigation quantity of 2800 m^3 /fed throughout the entire growing season of 2012 and 2013

7- Reference evapotranspiration (ET_0)

The results of ET_0 in Table (7) show that ET_0 rate values seemed to be high during July and August, then decreased gradually during September and October in the two seasons. These results may be attributed to the changes in the weather factors. These results are confirmed with those reported by Allen *et al.* (1998), whom mentioned that the ET_0 values are mainly depended on the evaporative power of air temperature, wind speed, relative humidity and solar radiation.

8- Crop coefficient (K_C)

The K_C value reflects the effect of the crop cover percentage on the ET_0 values.The K_C values recorded in Table (7) reveal that the K_C values for the highest seed yield interaction i.e. applying 60 kgNfed^{-1} level as liquid ammonia and irrigating with 2800 m3 /fed per the season, were started low during July (initial growing season). Thereafter, the K_C values were increased during August (establishment and rapid vegetative growth stages) and reached its maximum values at September (maximum growth and heading stages). The K_C values decreased again during October (maturity and harvesting stage). The obtained results were found to be true in 2012 and 2013 seasons. Such findings may be referred to the high diffusive resistance of the bare soil during the initial growing stage (July), which reduced by increasing the crop cover percentage until maximum vegetative growth (August) and anthesis stage (September). However, at late season (October) the transpiration decreased sharply, as the most plant leaves became dry. These results are in the same trend with those reported by Doorenbos et al. (1979), Abdou et al. (2011) and Ashry et al. (2013).

Table7:Reference evapotranspiration rates (ET_0), daily ET_C (mmday^{-1}) and crop coefficient (K_C) values of sunflower for the highest yielding interaction (60 kgNfed^{-1} and irrigating with 2800 m^3/fed water rate) during 2012 and 2013 growing seasons

Season	2012 season			2013 season		
Month	ET_0 (mmday^{-1})	ET_C (mmday^{-1})	K_C	ET_0 (mmday^{-1})	ET_C (mmday^{-1})	K_C
July	7.79	4.51	0.58	7.34	4.11	0.56
August	7.30	5.48	0.75	7.53	5.80	0.77
September	6.64	6.18	0.93	6.66	6.46	0.97
October	5.20	3.12	0.60	5.80	3.65	0.63

9- Water use efficiency (W.U.E)

The WUE values expressed as, kg seeds m^{-3} of water consumed by the crop are presented in Table (8). Water use efficiency values, as a function of N fertilization levels and irrigation water quantities rates interaction were 0.363 and 0.373 kg seedsm^{-3} water consumed in 1st and 2nd seasons, respectively. The highest WUE values e.g. 0.375 and 0.383 kg seeds/m^3 water consumed were recorded with 50 kgNfed^{-1} level in 2012 and 2013 seasons, respectively. Nevertheless, the lowest WUE values, i.e. 0.350 and 0.361 kg seeds/m^3 water consumed was obtained with 40 kgNfed^{-1}

fertilization level in 1st and 2nd seasons, respectively. These results are in accordance with those found by Ashry *et al.* (2013).

Regarding the effect of irrigation water rate on WUE, data in Table (8) reveal that the highest irrigation rate (2800 m^3fed^{-1})gave the highest WUE i.e. 0.370 and 0.380 kg $seedsm^{-3}$ water consumed in 1^{st} and 2^{nd} seasons, respectively. On the other hand, the lowest WUE values, i.e. 0.360 and 0.367 kg seeds/m^3 water consumed resulted from plants received 2200 m^3water/fed in 1^{st} and 2^{nd} seasons, respectively. These results may be due to that increasing irrigation water quantity to 2800 m^3/fed caused a remarkable increase in seed yield more than the increase in ET_C comparing with 2200 m^3/fed. rate These results are in harmony with those reported by Attia *et al.* (1990), Abdou *et al.* (2011) and Ashry *et al.* (2013).

Table (8).Effect of N fertilization levels, irrigation water quantities and their interaction on water use efficiency (kg seeds/m^3 water consumed) for sunflower crop in 2012 and 2013 seasons

N fertilization rate ($kgNfed^{-1}$)	2012 season				2013 season			
	Irrigation water quantity (m^3fed^{-1})			Mean	Irrigation water quantity (m^3fed^{-1})			Means
	2300	2500	2800		2300	2500	2800	
40	0.345	0.337	0.367	0.350	0.351	0.359	0.374	0.361
50	0.374	0.369	0.372	0.375	0.382	0.378	0.390	0.383
60	0.362	0.362	0.372	0.365	0.369	0.377	0.376	0.374
Mean	0.360	0.356	0.370	0.363	0.367	0.371	0.380	0.373

With respect to the interaction effect of N fertilization levels and irrigation water rates on WUE values, data in Table (8) indicate that the highest WUE values, e.g. 0.374 kg seeds/m^3 water consumed in 2012 season was detected from applying 50 $kgNfed^{-1}$ as liquid ammonia and irrigated with 2200 m^3 water/fed level, whereas, in 2013 season the highest WUE value, i.e. 0.390 kg seeds/m^3 water consumed resulted from applying 50 $kgNfed^{-1}$ as liquid ammonia and irrigation with 2800 m^3 fed^{-1} level, but the difference between 2800 and 2200 m^3 fed^{-1} levels could be negligible. Therefore, it could be concluded that applying 50 kg $Nfed^{-1}$ as liquid ammonia and irrigating with 2200 m^3 water /fed/season is advisable due to saving in both applied water and N as well.

10-Irrigation water productivity (WP)

The water productivity, expressed as kg seeds/m^3 water applied during the entire growing season of the crop in both seasons are presented in Table (9). Data show that increasing N fertilization level from 40 to 50 or 60 $kgNfed^{-1}$ increased WP values from 0.247 to 0.279 and 0.294 kg seeds/m^3 water applied in 2012 season and from 0.258 to 0.293 and 0.306 kg seeds/m^3 water applied in 2013 season, respectively. It is evident that the water productivity increased as the rate of N fertilization increased up to 60 $kgfed^{-1}$.

Regarding the response of WP to adopted irrigation treatments,data reveale that the highest WP values (0.288 and 0.298 kg seeds/m^3 water applied) resulted from irrigating with 2200 m^3 water/fed rate in 2012 and 2013 seasons, respectively. Increasing irrigation water applied to be 2500 or 2800

m^3/fed tended to decrease WP values by 6.60 and 8.68% in 2012 season and by 4.36 and 8.05% in 2013 one, respectively, comparable with 2300 m^3/fed/season.

The interaction clear out that the highest WP values (0.309 and 0.321 kg seeds/m^3 water applied)in 2012 and 2013, respectively, were detected from applying 60 kgNfed^{-1} under irrigating at 2200 m^3/ fed water rate. Under the conditions of the present investigation and in order to conserve the limited irrigation water resources, it is advisable to grow sunflower under 60 kgNfed^{-1} fertilization level and irrigating at 2200 m^3 water/fed rate.

Table (9).Effect of ammonia gas levels, irrigation water quantities and their interaction on water productivity (kg seeds/m^3 water applied) for sunflower crop in 2012 and 2013 seasons

N fertilization rate (kgNfed^{-1})	2012 season				2013 season			
	Irrigation water quantity (m^3fed^{-1})				Irrigation water quantity (m^3fed^{-1})			
	2300	2500	2800	Mean	2300	2500	2800	Mean
40	0.257	0.241	0.244	0.247	0.264	0.260	0.250	0.258
50	0.298	0.277	0.261	0.279	0.310	0.289	0.280	0.293
60	0.309	0.289	0.283	0.294	0.321	0.306	0.292	0.306
Mean	0.288	0.269	0.263	0.273	0.298	0.285	0.274	0.286

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إستجابة محصول عباد الشمس والعلاقات المائية للتسميد بالامونيا السائلة وكميات مياه الري

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بطامية – محافظة الفيوم خلال موسمي 2012 ، 2013 لدراسة تأثير ثلاثة مستويات التسميد النتروجيني في صورة أمونيا سائلة وهي 40 ، 50 ، 60 كجم نتروجين /ف (1 كجم امونيا يحتوي علي 82,5 % نيتروجين) مع ثلاثة كميات لماء الري في الموسم وهي 2200 ، 2500 ، 2800 م3 /ف وذلك في تصميم الشرائح المتعامده ذو اربعة مكررات وذلك علي المحصول ومكوناته وبعض العلاقات المائية للمحصول وكانت أهم النتائج المتحصل عليها كما يلي:

1- تأثر المحصول ومكوناته معنوياً بمستويات التسميد النتروجيني في صورة أمونيا سائلة وكذلك بكميات مياه الري المضافة في كلا الموسمين.

2- كانت أعلي متوسطات لارتفاع النبات، قطر القرص ووزنه، وزن بذور القرص، وزن ال100 بذرة ومحصول بذور الفدان (792,15 ، 816,49 كجم/ف في 2012 ، 2013 علي الترتيب) قد نتجت من حقن التربة ب 60 كجم ن/ف في صورة أمونيا سائلة والري ب 2800 م3 /ف ، بينما نتجت أقل المتوسطات لمكونات المحصول ومحصول البذور (565,61 ، 580,52 كجم/ف) من حقن التربة ب 40 كجم ن/ف والري ب 2200 م3/ف وقد أعطت معاملة إضافة 40 كجم ن/ف والري ب 2800 م3 ماء /ف أعلي نسبة زيت بالذور وهي 42,23 ، 42,31% في 2012 ، 2013 علي الترتيب..

3- وصل الاستهلاك المائي الموسمي لأعلي قيمة له (50,76 ، 51,77 سم في 2012 ، 2013) من حقن التربة ب 60 كجم ن/ ف في صورة أمونيا سائلة والري ب 2800 م3 / ف وكان ثابت المحصول (K_C) خلال موسم النمو 0,57 ، 0,76 ، 0,95 ، 0,62 خلال يوليو ، أغسطس ، سبتمبر ، أكتوبر (متوسط للموسمين) علي الترتيب.

4- حقن التربة ب 50 كجم ن/ف وإضافة 2200 م3 ماء للفدان هي أحسن المعاملات في كفاءة إستهلاك ماء الري بواسطة المحصول والتي كانت 0,374 ، 0,382 كجم بذرة /م3 ماء مستهلك في موسمي 2012 ، 2013 علي الترتيب . بينما كانت أعلي إنتاجية من وحدة المياه المضافة هي 0,309 ، 0,321 كجم بذور / م3 ماء مضاف قد نتجت من حقن التربة بواسطة 60 كجم ن/ف في صورة امونيا سائلة والري ب 2200 م3 ماء / فدان في كلا الموسمين.