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Sunflower yield and some water relations under irrigation regimes and nitrogen fertilization.

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Abstract

The present investigation was carried out at Tamiea Agric. Res. Station, Fayoum Governorate during 2009 and 2010 seasons to study the effects of irrigation regimes, i.e. irrigation at I_1: 30%, I_2: 50% and I_3: 70% available soil moisture depletion (ASMD) and three nitrogen levels, i.e. N_1: 30, N_2:50 and N_3:70 kg N fed^{-1} and their interaction on yield, yield components and some crop water relations of sunflower (Eroflour cv.). The split-plot design with four replicates was used. The obtained results were as follow:

yield and all yield components i.e. plant height, head diameter and weight, seed weight $head^{-1}$, 100- seed weight and seed protein content, obtained from irrigating sunflower at 30% ASMD and applying 70% kg N fed^{-1}, surpassed significantly those obtained from the other treatments. However, the highest oil content were detected from irrigating sunflower at 30% ASMD and applying 30 kg N fed^{-1}.

Seasonal water evapotranspiration (ET_C) reached its maximum values (58.81 and 57.74 cm in 2009 and 2010 seasons, respectively), as sunflower crop was irrigated at 30% ASMD and fertilized by 70 kg N fed^{-1}.

The daily ETc increased by decreasing the ASMD from 70 to 50 to 30% ASMD. The peak of daily ETc occurred on July. The K_C (crop coefficient) as means during the growing seasons were 0.48, 0.79, 0.62, and 0.39 for June, July, August and September months, respectively.

Irrigation at 30% ASMD and applying 50 kg N fed^{-1} gave the highest water use efficiency, i.e. 0.440 and 0.452 kg seeds m^{-3} water consumed in 2009 and 2010 seasons, respectively.

Key words: Sunflower, yield and yield components, evapotranspiration Kc and water use efficiency.

Introduction

Sunflower (*Helianthus annuus L.*) is the second oil crop after cotton in Egypt. Great emphasis has been given to increase its production per unit area. The response of sunflower plants to nitrogen fertilization at different soil types and environments must be optimized for high yield. Irrigation water management nowadays play an important role in our agricultural strategy due to the expansion in the new reclaimed area under our limited water resources. Thus irrigation development for saving water throughout agricultural treatments became a very necessary for high efficiency use of water.

El- wakil and Gaafar (1986) found that increasing available soil moisture depletion (ASMD) from 40 to 60 or 80% caused a significant decrease in head diameter of sunflower crop by 3.5 and 7.1 cm, seed yield fed^{-1}. by 174.3 kg and 276.2 kg fed^{-1}, oil percentage by 3.4 and 4.33% and oil yield fed^{-1}, by 100.2 kg and 139.8kg/fed, respectively. **Attia *et al.* (1990)** reported that irrigating sunflower plants at 25% available soil moisture significantly decreased head diameter, seed yield $plant^{-1}$, 100- seed weight and seed yield fed^{-1} by 37.2%, 41.1%, 46.5%, 40.6% , 4.1% and 43.5%, respectively compared to those irrigated at 75% available soil moisture. **Sharma (1994)** pointed out that increasing number of irrigation from one to three caused a significant increase in head diameter and seed yield by 1.7 cm and 3.9 ton $ha.^{-1}$, respectively, whereas the 1000-seed weight did not increase.

El- wakil and Gaafar (1986) showed that the seasonal crop evapotranspiration (ETc) decreased from 1492.0 to 1215.5 and 1084.0 m^3 water fed^{-1}, as the soil moisture depletion increased from 40 to 60 or 80% ASMD, respectively. They added that the highest water utilization efficiency (WUE) values were found to be; 1.24kg seeds m^{-3} water consumed which obtained from irrigation at 60% ASMD. **Attia *et al.* (1990)** reported that the water use by sunflower crop has been increased from 1611.5 to 1748.5 and 1824.1 m^3/fed, when irrigation was applied at 75%, 50% and 25% of ASMD, respectively. **Green and Read (1993)** concluded that the sunflower crop was very responsive to soil moisture stress and decreasing available soil moisture decreased dry matter production m^{-3} water consumed. However, the total water use increased from 12.4 cm^3 to 34.11 cm^3 as the soil moisture increased from slightly above wilting point to the field capacity level. **Kumar *et al.* (1991)** found that oil content increased with increasing soil moisture. **Abdou *et al.* (2011)** reported that the highest sunflower yield and yield components, seasonal evapotranspiration (51.21 cm) and daily ETc were obtained from irrigation at 1.2 C.P.E(cumulative pan evaporation) (short intervals), and the crop coefficient (Kc) values of the growing season were 0.44, 0.73, 0.98 and 0.63 for June, July, August and September. The highest WUE (0.408 kg seed/m^3 water consumed) was resulted from the wet treatment (short intervals).

Regarding the effect of nitrogen fertilization, **Karami (1980)** obtained that application of 50 kg, N ha^{-1}, increased the seed yield, plant height, head diameter and 100- seed weight and he added that higher rates of N produced no additional significant responses on yield or yield components, whereas oil percentage decreased with increasing nitrogen rate. **Mohammed and Rao (1981)** found that oil content slightly increased with 40 kg N ha-1, but decreased with 80-120 kg N ha-1. **El- sayed *et al.* (1984)** found that plant height, stem diameter, head diameter, 1000- seed weight and seed yield were significantly increased by increasing the level of applied nitrogen up to 50 N/ fed. On the other hand, oil percentage decreased by increasing level of nitrogen. **Saleh *et al.* (1984)** indicated that increasing nitrogen application increased seed yield and its components. **Satyanarayana *et al.* (1985)** found that application of 60 kg N ha^{-1}, gave the highest seed yield.

However, **Samui *et al.* (1987)** found that application of nitrogen significantly increased the oil yield. **Tripathi and Sawhney (1989)** indicated that application of nitrogen decreased oil content from 43.02% (0 kg N ha^{-1}) to 39.66% (60 kg N ha^{-1}).

Salib *et al.* (1998) reported that the highest sunflower yield, yield components and seed oil content were obtained from the interaction between applying 45 kg N fed^{-1} and irrigating plants sown on furrows of 60 cm width

Materials and Methods

Two field experiments were conducted at the Farm of Tameia Res. Station, Fayoum Governorate during 2009 and 2010 seasons Thus, three irrigation regimes, i.e. I_1: irrigation at 30% available soil moisture depletion (ASMD), I_2: irrigation at 50% ASMD and I_3: irrigation at 70% ASMD were combined with three nitrogen fertilization levels, i.e. N_1: 30, N_2: 50 and N_3: 70 kg N fed^{-1} in a split-plot design with four replications. The main plots were the irrigation treatments, whereas the sub-main plots were nitrogen levels. The sub-plot area was (3×7 m) six ridges of 7m length and 0.5m width. The sub-plots were isolated from each other's by dikes of 1.5m between to avoid the horizontal water seepage. Calcium super phosphate (15.5% P_2O_5) at the rate of 200 kg fed^{-1} was added during field preparation, whereas the nitrogen fertilization level treatments as ammonium nitrate 33.5% N were (at the 1st and 2nd irrigations) applied in two equal doses (seedling and early vegetative growth stages). Sunflower seeds of Eroflour cv. at the rate of 5.0 kg/fed were planted in hills of 20 cm apart on June 2nd and 6th in the two successive seasons, whereas harvesting was on 19 and 24 September in the first and second seasons, respectively. The physical and chemical analysis of the experimental plots soil were done according to **Page *et al.* (1982)** and **Klute (1986)** and presented in Table (1). The averages of Fayoum climatic factors during the two growing seasons are recorded in Table (2). The soil moisture constants of the experimental soil are shown in table (3). The soil moisture values were gravimetrically determined on oven dry basis, for different soil layers each of 15.0 cm from the soil surface and down to 60.0 cm depth, as the technique of Water Requirements and Field Irrigation Dept., A.R.C., Egypt.To reach the percentage of depletion from available soil moisture, soil samples were taken 48 hours after each irrigation daily and moisture percentage in samples were determined on oven dry basis until reaching the ASMD. For each irrigation treatment. Irrigation dates, intervals and count for different irrigation regime treatments are listed in Table (4). At harvesting time the following data were recorded from each sub- plot:

Yield and yield components

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

Crop water relations

- **Seasonal consumptive use** (ETc).

To determine crop water evapotranspiration (ETc), soil samples were taken from each sub-plot, just before and after 48 hours irrigation, as well as at harvesting time. The ETc between each two successive irrigations was calculated according to the following equation: **(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}). D = Soil layer depth (cm).

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

Calculated from the evapotranspiration value of each month, and divided by the number of days/ month.

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

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

- **Crop coefficient (Kc).**

The values of Kc were calculated as follows:

$$K_C = ET_C / ET_0 \quad \dots\dots\dots$$

Where

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

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

- **Water use efficiency (WUE)**

The WUE, as kg grains/ m^3 water consumed was calculated for different treatments as the equation described by **Vites (1965):**

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

Table 1. Physical and chemical analysis of the experimental field during 2009 and 2010 seasons (average of two seasons)

A. Physical analysis:

Sand%	Silt%	clay %	Texture class	orgonic matter %	Ca CO_3%
26.32	41.77	31.91	clay laom	1.72	4.92

B. Chemical analysis:

ECe ds/m	PH 1:2.5 extract	Soluble cation meg/L				Soluble anions meg/L				CEC meg/100 gm soil
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3	CO_3	SO_4	
6.72	8.10	14.91	11.12	42.32	0.42	35.12	1.91	-	31.74	39.22

Table 2. The monthly averages of climatic factors for Fayoum Governorate during 2009 and 2010 seasons.

Month	Year	Temperature (cȯ)			Relative humidity%	Wind speed m/sec.	Pan* evaporation (mm/day)
		Max.	Min.	Mean			
June	2009	38.2	20.4	29.3	44	2.99	8.18
	2010	38.4	21.4	29.9	48	3.01	7.60
July	2009	38.5	22.7	30.6	47	2.58	8.41
	2010	36.3	22.4	29.3	50	2.58	8.60
August	2009	37.0	21.8	29.4	48	2.42	7.62
	2010	40.2	24.5	32.3	46	2.44	7.00
September	2009	35.2	20.7	27.9	50	2.58	6.69
	2010	36.2	21.9	29.1	50	2.60	6.10

* After Fayoum meteorological station (Tameia destrict)

Table 3. The soil moisture constants of the experimental field sits during 2009 and 2010 growing seasons (average of the two seasons)

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Bulk density (g/cm^3)	Available moisture (%)
0- 15	39.32	19.92	1.32	19.40
15- 30	38.31	17.32	1.52	20.99
30- 45	33.41	16.31	1.41	17.10
45-60	28.77	13.21	1.37	15.56

Table 4. Dates of irrigation, irrigation intervals and irrigations count, as affected by irrigation treatments in 2009 and 2010 seasons

Number of irrigation	Season 2009						Season 2010					
	Irrigation treatments						Irrigation treatments					
	I_1 30% ASMD		I_2 50% ASMD		I_3 70% ASMD		I_1 30% ASMD		I_2 50% ASMD		I_3 70% ASMD	
	Date	Interval (days)	Date	Interval (days)	Date	Interval (days)	Date	Interval (days)	Date	Interval (days)	Date	Interval (days)
Planting	2/6	-	2/6	-	2/6	-	6/6	-	6/6	-	6/6	-
1st	17/6	15	17/6	15	17/6	15	21/6	15	21/6	15	21/6	15
2nd	28/6	11	2/7	15	7/7	20	3/7	12	7/7	16	10/7	19
3rd	10/7	12	18/7	16	10/7	21	14/7	11	22/7	15	30/7	20
4th	22/7	12	3/8	16	28/7	19	26/7	12	6/8	15	20/8	21
5th	2/8	11	19/8	16	16/8	19	8/8	13	21/8	17	10/9	21
6th	14/8	12	5/9	17	4/9	-	21/8	13	6/9	16	-	-
7th	26/8	12	-	-	-	-	6/9	16	-	-	-	-
8th	9/9	14	-	-	-	-	-	-	-	-	-	-
Harvest	19/9	10	19/9	14	19/9	15	24/9	18	24/9	18	24/9	14

Results and Discussion

I. Yield, yield components, protein and oil content of seeds

Results in Table (5) show that seed yield and its components were decreased significantly with 50 or 70 ASMD compared with 30% ASMD and these results were true in 2009 and 2010 seasons. The highest averages of plant height. Head diameter, head weight, seed weight head^{-1}, 100-seed weight, seed protein content, seed yield and seed oil content , were obtained under 30% ASMD. It is clear that under 50 and 70% ASMD, sunflower yield was decreased by 16.18 and 50.03 %, in 2009 season, respectively, and in 2010 season by 11.35 and 47.01%, respectively, compared with 30% ASMD, these results may be referred to the effect of water deficit resulted from the wide irrigation cycle under 70% ASMD irrigation treatment, which in turn reduced photosynthesis, cell division, stem elongation, leaf area, leaf duration and dry matter accumulation in plant organs. The obtained results are in the same line with those reported by **El- wakil and Gaafar (1986) and Attia *et al.* (1990).**

Regarding the effect of N fertilizer level effect, data in Table (5) show that applying 70 kg N fed^{-1} caused remarkable increases in seed yield and yield components than 50 or 30 kg N fed^{-1}. Applying 30 kg N fed^{-1} significantly reduced plant height, head diameter, head weight, seed weight head^{-1}, 100-seed weight, protein content and seed yield fed^{-1} by 9.28, 24.81, 44.37, 23.16, 33.33, 7.88 and 48.28% in 2009 season, respectively, and in 2010 season by 9.50, 25.9, 45.11, 22.44, 13.09, 8.68 and 53.65%, respectively, when compared with 70 kg N fed^{-1}. On contrast the oil content of seeds decreased by increasing N level in both seasons. The obtained results of yield and yield components may be due to at the high level of nitrogen, the plant growth increased, as increasing the cell division and cell elongation as well as increasing the dry matter accumulation which in turn caused more metabolized translocation to the plant head and seeds. These results are in agreement with those obtained by **Satyanarayana et al. (1985) and Samui et al. (1987).** The data recorded in Table (5) indicate that, yield and yield components were significantly affected by the interaction between irrigating and N level treatments in both seasons. Irrigation at 30% ASMD and applying 70 kg N fed^{-1} resulted in the highest averages of yield and its components in the two seasons. The lowest ones were obtained from irrigating at 70% ASMD and applying 30 kg N fed^{-1} in both seasons. On the other hand the highest averages of oil content i.e. 42.92, 42.63 in 2009 and 2010 seasons, respectively, were detected from irrigating at 30 % ASMD and applying 30 kg N fed^{-1}. These results are in agreement with those obtained by **Salib *et al.* (1998).**

II. Crop water relations

1. Seasonal crop evapotranspiration

The results presented in Table (6) show that the values of seasonal evapotranspiration of sunflower (ETc), as a function of irrigation regimes, N fertilization_levels and their interactions were 49.35 and 48.92 cm in 2009 and 2010 seasons, respectively. Irrigation at 30% ASMD gave the highest values of ETc, i.e._53.85 and 52.48 cm in the two successive seasons, whereas the lowest values of ETc. i.e. 44.02 and 44.05 cm were obtained from irrigation at 70% ASMD (dry treatment) in 2009 and 2010 seasons, respectively. Increasing the ASMD from 30 to 50 or 70% ASMD decreased the ETc of sunflower in 2009 season by 6.83, and 18.25%, and in 2010 season by 4.27 and 16.06% respectively. These results attributed to that increasing the available soil moisture depletion may reduce the evaporation from soil surface and the transportation from plants as a result of the reduction in vegetative growth caused by irrigation at long intervals. These results are in agreement with those reported by **El-Wakil and Gaafar (1986) and Attia *et al.* (1990).**

The data illustrated in Table (6) reveal that the seasonal ETc values of sunflower were increased as nitrogen fertilization level applied increased. Increasing N fertilization level applied from 30 to 50 or 70 kg N fed-1 resulted in increasing ETc in 2009 season by 8.60 and 17.28%, respectively, and in 2010 season by 9.76 and 18.83%, respectively. Applying 30 kg N fed-1 gave the lowest values of ETc, i.e. 45.43 and 44.66 cm in the two successive seasons, whereas the highest ones, i.e. 53.28 and 53.07 cm were detected from applying 70 kg N fed-1. These results may be referred to that increasing N fertilization level to 70 kg N fed-1 gave vigorous vegetative growth, as higher availability of nitrogen, which in turn increased transpiration from plants. These results are in harmony with those found by **El-Sayed *et al.* (1984) and Saleh *et al.* (1984).**

Regarding the effect of the interactions between irrigation regime treatments and nitrogen fertilization levels on seasonal ETc, results in Table **(6)** indicate that the highest ETc values, i.e. 58.81 and 57.74 cm were resulted from irrigating sunflower plants at 30% ASMD (wet treatment) and applying 70 kg N fed-1 in 2009 and 2010 seasons, respectively. Irrigation at 70% ASMD and applying 30 kg N fed-1 gave the lowest Etc values, i.e. 41.06 and 41.13 cm (I_3 N_1 treatment) in the two successive seasons.

Table 5. Effect of irrigation regimes, nitrogen fertilization levels and their interaction on sunflower yield components, seed yield as well as seed protein and oil contents in 2009 season

Treatment		Plant height (cm)		Head diameter (cm)		Head weight (g)		Seed weight head^{-1} (g)		100- seed weight (g)		Seed yield (kg fed^{-1})		Seed protein content (%)		Seed oil content (%)	
Irrigation regimes ASMD	**Nitrogen levels kg/fed**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
(I_1) 30%	N_1: 30 kgN/fed	175.3	173.8	14.91	14.03	292.0	268.0	70.15	69.95	6.41	6.21	712.3	697.3	11.72	11.63	42.92	42.63
	N_2: 50 kgN/fed	181.0	180.6	17.00	16.81	385.0	365.0	82.11	81.63	7.52	7.47	991.6	1005.2	12.26	12.08	42.66	41.92
	N_3: 70 kgN/fed	187.7	189.3	18.86	17.94	406.0	402.0	89.66	88.24	7.89	7.75	1050.2	1066.4	12.94	12.66	41.94	40.66
	Mean	181.3	181.2	16.92	16.26	361.0	351.0	80.64	79.94	7.27	7.14	918.3	923.0	12.31	12.12	42.51	41.74
(I_2) 50%	N_1: 30 kgN/fed	160.0	162.4	13.06	12.92	253.0	248.0	62.17	61.03	5.01	5.25	580.4	592.7	11.97	11.89	41.26	41.31
	N_2: 50 kgN/fed	168.3	170.1	15.52	15.16	340.0	327.0	68.15	67.44	6.45	6.31	883.2	919.5	12.81	12.94	41.05	40.88
	N_3: 70 kgN/fed	176.5	177.7	16.87	16.22	375.0	363.0	77.32	73.71	6.98	6.87	907.5	974.6	1303	13.11	40.12	40.03
	Mean	168.3	177.1	15.15	14.77	322.7	312.7	69.21	67.39	6.15	6.14	790.4	828.9	12.60	12.65	40.81	40.74
(I_3) 70%	N_1: 30 kgN/fed	151.7	153.5	12.77	12.34	219.0	211.0	54.94	54.00	4.06	4.18	486.3	496.6	12.84	12.79	40.57	40.89
	N_2: 50 kgN/fed	159.3	160.4	14.21	14.00	298.0	304.0	60.13	61.63	5.15	5.32	669.1	682.8	13.07	13.11	40.22	40.47
	N_3: 70 kgN/fed	168.0	169.1	15.13	15.28	322.0	316.0	63.67	64.56	5.76	5.85	680.3	704.1	13.46	13.68	39.84	39.04
	Mean	159.7	161.00	14.04	13.87	279.7	277.0	59.58	60.06	4.99	5.12	611.9	627.8	13.12	13.19	40.21	40.13
Nitrogen Levels means	N_1: 30 kgN/fed	162.33	163.2	13.58	13.09	254.67	248.3	62.42	61.66	5.16	5.21	593.00	595.5	12.18	12.10	41.58	41.61
	N_2: 50 kgN/fed	169.53	170.4	15.58	15.32	341.00	332.0	70.13	70.23	6.37	6.37	847.97	869.2	12.71	12.71	41.31	41.09
	N_3: 70 kgN/fed	177.40	178.7	16.95	16.48	367.67	360.3	76.88	75.50	6.88	6.82	879.33	915.0	13.14	13.15	40.63	39.91
L.S.D.: at 5%																	
	I	1.42	1.25	0.27	0.27	5.64	7.58	0.48	1.51	0.22	0.32	3.93	2.75	0.19	0.19	0.35	0.19
	N	0.82	0.87	0.13	0.05	1.46	3.13	0.39	1.13	0.11	0.08	1.35	1.53	0.10	0.11	0.17	0.07
	I × N	1.41	1.39	0.23	0.10	2.53	5.42	0.68	1.95	0.19	0.14	2.34	2.65	0.17	0.15	0.29	0.12

Table 6. Effect of irrigation regimes, nitrogen fertilization levels and their interactions on seasonal evapotranspiration (ETc) of sunflower in 2009 and 2010 seasons.

Season	2009 season				2010 season			
Irrigation regimes	Nitrogen levels (kg N fed-1)				Nitrogen levels (kg N fed-1)			
	30	50	70	Mean	30	50	70	Means
I_1: 30% ASMD	49.14	53.61	58.81	53.85	47.43	52.26	57.74	52.48
I_2: 50% ASMD	46.10	50.11	54.31	50.17	45.44	50.10	55.18	50.24
I_3: 70% ASMD	41.06	44.31	46.71	44.02	41.13	44.71	46.31	44.05
Mean	45.34	49.34	53.28	49.35	44.66	49.02	53.07	48.92

2. **Daily ETc rate**

The data recorded in Table (7) show that the daily ETc rate, as a mean of the different treatments of this study (over all mean) started with low values during June, i.e. 3.93 and 3.94 mm/day in 2009 and 2010 seasons, respectively. Thereafter, the daily ETc rate increased during July reaching its maximum values (6.55 and 6.31mm/day in the two successive seasons), then it declined again during August and reached its minimum values during September. These results may be attributed to that during June most of water losses were resulted from the evaporation of bare soil (germination and seedling stages), thereafter, as the crop growth increased the daily ETc increased because transpiration from plants took place besides evaporation from soil, reaching its peak values at anthesis stage. The ETc rate redecreased again during August, as a result of leave drying and physiological maturity.

Results in Table (7) indicate that increasing ASMD from 30% to 50% or 70% decreased the ETc rates during all the growing season months from June to September, since increasing the soil moisture stress had a significant effects on plant growth and photosynthesis activities, as well as decreasing transpiration from plants.

Regarding the effect of N fertilization levels on daily ETc rates, the presented data in Table (7) point out that increasing N fertilization levels applied from 30 to 50 and 70 kg N fed-1 resulted in increasing ETc rate (mm/day) during all the growing months duration from
June to September. These results may be due to that increasing N level caused increasing in vegetative growth of plant, which gave an increase effect of plant transpiration.

The highest values of daily ETc rates was occurred from irrigation at 30% ASMD (wet treatment) and applying 70 kg N fed^{-1} during the growing season duration months.

3. **Reference evapotranspiration (ET_0)**

The daily ET_0 rates (mm/day) during sunflower growing seasons of 2009 and 2010 are shown in Table (8). The daily ET_0 values were estimated using the daily meteorological data of Fayoum Governorate (Table, 2) and the FAO- Penman-Monteith equation from June to September in both seasons. The results showed that the daily ET_0 rates were started with high values during June month and slowly declined during July with continuous decrease during August and September in the two seasons. These results may be referred to the changes in climatic factors from month to another. With respect to these results, **Allen *et al.* (1998)** reported that the values of reference evapotranspiration are mainly depended on the evaporative power of the air, i.e. temperature degrees, relative humidity, wind speed and solar radiation.

4. **Crop coefficient**

The crop coefficient (Kc) values reflect the crop cover percentage over the soil and the reference evapotranspiration values during the period of estimation. The Kc values were calculated from the daily ETc rates (Table, 7) and the daily ET_0 values in Table (8) during the months of the two growing seasons duration. The results presented in Table (8) reveal that the Kc values, as a function of irrigation regimes, N fertilization levels and their interactions (over all mean) were low during June month (germination and seedling growth stages). The Kc values thereafter increased during July to reach its maximum values (vegetative growth and anthesis stages), then the Kc values redecreased again during August (seed filling and physiological maturity) and reached its minimum values in September (harvesting stage). These results were found to be true in the two growing seasons 2009 and 2010. Such findings may be due to the high diffusive resistance of the bare soil during June (initial growth period), which decreased by increasing the crop cover until maximum growth and anthesis stage (mid-July to mid August). However, at seed filling (late season) transpiration rates decreased, as most plant leaves became dry.

Generally, the Kc values for sunflower to have high seed production were 0.59, 1.02, 0.75 and 0.37 in 2009 season and 0.59, 0.95, 0.73 and 0.51 in 2010 season during June, July, August and September, respectively, under irrigation at 30% ASMD and applying 70 kg N fed^{-1} treatment.

5. **Water use efficiency**

The water use efficiency expressed as the productivity of seeds in kg, detected from each cubic meter evapotranspiration by the crop (kg seeds/ m^3 water) are listed in Table (9).

The data recorded in Table (9) show that the W.U.E. values, as a function of irrigation regimes, N fertilization levels and their interactions in 2009 and 2010 seasons were 0.368 and 0.380 kg seeds/ m^3

water consumed, respectively. Irrigation at 30% ASMD gave the highest W.U.E. values, i.e. 0.403 and 0.414 kg seeds/ m^3 water consumed in 2009 and 2010 seasons, respectively. However, the lowest ones, i.e. 0.282 and 0.287 kg seeds/ m^3 water consumed in the two successive seasons, were observed from irrigation at 70% ASMD (dry treatment). These results may be due to that in the case of dry treatment the reduction in seed yield was much more that the decrease in seasonal evapotranspiration detected from this treatment, when compared with those of irrigation at 30% ASMD. These results are in accordance with the results found by **Attia *et al*, (1990).**

Table 7. Effect of irrigation regimes, nitrogen fertilization levels and their interactions on the daily evapotranspiration (ETc) rates (mm day^{-1}) during the monthly of 2009 and 2010 seasons

Treatments		2009 season				2010 season			
Irrigation regimes ASMD	Nitrogen fertilizer (kg/fed)	June	July	August	Spe.	June	July	August	Spe.
(I_1) 30%	30 kgN/fed	4.01	6.09	4.66	2.33	4.05	6.10	4.19	2.11
	50 kgN/fed	4.56	6.45	5.25	2.14	4.51	6.39	4.85	2.58
	70 kgN/fed	4.82	7.89	5.28	2.23	4.73	7.19	5.19	3.14
Mean		4.49	6.81	5.06	2.23	4.43	6.53	4.74	2.61
(I_2) 50%	30 kgN/fed	3.42	6.34	4.12	2.11	3.41	6.10	4.12	2.15
	50 kgN/fed	4.22	6.48	4.52	2.18	4.16	6.19	4.28	3.10
	70 kgN/fed	4.45	7.15	4.78	2.45	4.47	7.41	4.38	3.15
Mean		4.03	6.64	4.47	2.97	4.01	6.57	4.26	2.80
(I_3) 70%	30 kgN/fed	3.03	6.17	3.11	1.95	3.39	5.15	3.71	2.13
	50 kgN/fed	3.09	6.11	4.12	2.02	3.02	6.02	4.12	2.51
	70 kgN/fed	3.65	6.33	4.02	2.24	3.70	6.29	3.95	2.13
Mean		3.26	6.20	3.75	2.07	3.37	5.82	3.93	2.26
Mean N									
N1 30 kg N fed-1		3.49	6.20	3.96	2.13	3.62	5.78	4.01	2.13
N2 50 kg N fed-1		3.96	6.35	4.63	2.11	3.90	6.20	4.42	2.73
N3 70kg N fed-1		4.31	7.12	4.69	2.31	4.28	6.96	4.51	2.81
over all mean		3.93	6.55	3.09	2.42	3.94	6.31	4.31	2.56

Table 8. Reference evapotranspiration, ET_0 (mm $days^{-1}$) and Kc values for sunflower crop during 2009 and 2010 seasons as affected by irrigation regimes and nitrogen fertilization levels.

Treatments		2009 season				2010 season			
Irrigation regimes ASMD	Nitrogen fertilizer kg/fed	June	July	August	Spe.	June	July	August	Spe.
Reference ET (ETo)		8.1	7.7	7.0	6.0	8.0	7.6	7.1	6.2
(I_1) 30% ASMD	30 kgN/fed	0.49	0.79	0.66	0.39	0.51	0.80	0.59	0.34
	50 kgN/fed	0.56	0.84	0.75	0.36	0.56	0.84	0.68	0.42
	70 kgN/fed	0.59	1.02	0.75	0.37	0.59	0.95	0.73	0.51
Mean		0.55	0.88	0.72	0.37	0.55	0.86	0.67	0.42
(I_2) 50% ASMD	30 kgN/fed	0.42	0.82	0.59	0.35	0.43	0.80	0.58	0.35
	50 kgN/fed	0.52	0.84	0.64	0.36	0.52	0.81	0.60	0.50
	70 kgN/fed	0.55	0.93	0.68	0.41	0.55	0.98	0.62	0.51
Mean		0.50	0.86	0.64	0.37	0.50	0.86	0.60	0.45
(I_3) 70% ASMD	30 kgN/fed	0.37	0.80	0.44	0.35	0.42	0.68	0.52	0.34
	50 kgN/fed	0.38	0.79	0.59	0.34	0.38	0.79	0.58	0.40
	70 kgN/fed	0.45	0.82	0.57	0.37	0.46	0.83	0.56	0.34
Mean		0.40	0.80	0.53	0.35	0.42	0.77	0.55	0.36
Mean N f.l									
	N_1 30 kgN/fed	0.43	0.80	0.56	0.36	0.45	0.76	0.56	0.34
	N_2 50 kgN/fed	0.49	0.82	0.66	0.35	0.49	0.81	0.62	0.44
	N_3 70 kgN/fed	0.53	0.92	0.67	0.38	0.53	0.92	0.64	0.45
Mean of K_C for all treatments		0.48	0.85	0.63	0.36	0.49	0.73	0.61	0.41

Regarding the effect of N fertilization levels on W.U.E. values, the obtained results in Table (9) reveal that applying 50 kg N fed-1 to sunflower plants gave the highest W.U.E. values, i.e. 0.406 and 0.417 kg seeds/ m^3 water consumed in 2009 and 2010 seasons, respectively. Whereas the lowest W.U.E. values, i.e. 0.308 and 0.315 kg seeds/ m^3 water consumed were detected from applying 30 kg N fed-1 in the two successive seasons. On the other hand, although the highest yields were resulted from applying 70 kg N fed-1 (Table 5), the treatment gave lower W.U.E. values than 50 kg N fed-1 level, i.e. 0.388 and 0.407 kg seeds/ m^3 water consumed in 2009 and 2010 seasons, respectively. These results may attributed to that the increase in seed yield from 50 and 70 kg N level were 3.7 and 5.27% in 2009 and 2010 seasons, respectively (Table 5) whereas the increases in seasonal ETc values from 50 to 70 kg N application reached 7.98 and 8.26%, in the two successive seasons (Table, 6). These results mean that increasing N fertilization level from 50 kg N to 70 kg N fed-1 resulted in much more increase in seasonal evapotranspiran than the increase in seed yield obtained. The results are in the same trend of those reported by **Saleh *et al.* (1984) and Samui et al, (1987)** The data recorded in Table (9) point out that the highest averages of W.U.E., i.e. 0.440 and 0.452 kg seeds/ m^3 water consumed were obtained from irrigating sunflower crop at 30% ASMD and applying 50 kg N fed-1 in 2009 and 2010 seasons, respectively. However, irrigation at 70% ASMD and applying 30 kg N fed-1 gave the lower values of W.U.E., i.e. 0.282 and 0.287 kg seeds/ m^3 water consumed in the two successive seasons.

Table 9. Effect of irrigation regimes, nitrogen fertilization levels and their interactions on water use efficiency values of sunflower crop (kg seeds m^{-3} water consumed) in 2009 and 2010 seasons.

Seasons	2009 season				2010 season			
Irrigation regims ASMD	Nitrogen levels (kg N fed^{-1})				Nitrogen levels (kg N fed^{-1})			
	30	50	70	Mean	30	50	70	Means
I_1: 30% ASMD	0.345	0.440	0.425	0.403	0.350	0.452	0.439	0.414
I_2: 50% ASMD	0.299	0.419	0.398	0.372	0.310	0.437	0.420	0.389
I_3: 70% ASMD	0.282	0.359	0.347	0.329	0.287	0.363	0.362	0.337
Mean	0.308	0.406	0.388	0.368	0.315	0.417	0.407	0.380

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محصول عباد الشمس وبعض العلاقات المائية تحت معاملات نقص رطوبة التربة والتسميد النيتروجيني

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أقيم هذا البحث بمحطة البحوث الزراعية بطامية – محافظة الفيوم خلال موسمي 2009 ، 2010 لدراسة تأثير نقص الرطوبة وهي الري عند فقد(I_1:30 ، I_2: 50 ، I_3: 70%) من رطوبة التربة الميسرة وثلاث مستويات تسميد نيتروجيني وهي (N_1: 30، N_2: 50 ، N_3: 70 كجم نيتروجين ف$^{-1}$) والتفاعل بينهما علي المحصول ومكوناته وبعض العلاقات المائية لعباد الشمس (صنف إيرفلور) وأستخدم في هذا البحث تصميم القطع المنشقة مرة واحدة في أربعة مكررات وكانت أهم النتائج المتحصل عليها كما يلي:

تفوقت إنتاجية المحصول ومكوناته (ارتفاع النبات – قطر القرص – وزن القرص – وزن بذور القرص – وزن ال100 بذرة – محتوي البذور من البروتين) معنوياً من ري عباد الشمس عند فقد 30% من رطوبة التربة الميسرة وإضافة 70 كجم نيتروجين ف$^{-1}$ عن المعاملات الاخري بينما أعلي محتوي زيت للبذرة قد نتج من الري عند فقد 30% من الماء الميسر وإضافة 30 كجم نيتروجين ف$^{-1}$.

كان أقصي إستهلاك مائي موسمي (58,81 ، 57,47 سم) في موسمي 2009 ،2010 علي التوالي قد نتج من الري عند فقد 30% من رطوبة التربة الميسرة وإضافة 70 كجم نيتروجين ف$^{-1}$.

الاستهلاك المائي اليومي إزداد بزيادة رطوبة التربة الميسرة . وكان أقصي إستهلاك يومي في شهر يوليو . كما كان ثابت المحصول (كمتوسط للموسمين) هو 0,48 ، 0,79 ، 0,62 ، 0,39 خلال يونيو و يوليو وأغسطس وسبتمبر علي الترتيب.

الري عند فقد 30% من الماء الميسر وأضافة 50 كجم نيتروجين للفدان أعطي أعلي كفاءة إستهلاك مائي وهي 0,440 ، 0,452 كجم بذور م$^{-3}$ ماء مستهلك في موسمي 2009 ، 2010 علي الترتيب.