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EFFECT OF MOISTURE DEFICIT AND FERTILIZATION ON SUNFLOWER CROP GROWN UNDER CALCAREOUS SOIL CONDITIONS

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The current work was carried out during summer season 2003 in the agricultural experimental station of the Desert Research Center at Maryut, Alexandria Governorate, Egypt. The study intends to evaluate the influence of soil moisture deficit, NPK fertilizer levels and their interaction on the yield and yield components of sunflower. Soil moisture content, soil temperature, actual evapotranspiration (ETa), water saving, water use efficiency (WUE), investment ratio (IR) and crop coefficient (Kc) of sunflower grown under calcareous soil conditions were estimated.

The treatments include: three soil moisture deficit levels from available soil water: (D_1 = 30 %, D_2 = 45 % and D_3 = 60 %) converted to irrigation intervals, three levels of NPK fertilizer (F_1: N = 45, P_2O_5 = 45 & K_2O = 24 kg/fed), (F_2: N = 55, P_2O_5 = 60 & K_2O = 48 kg/fed) and (F_3: N = 65, P_2O_5 = 75 & K_2O = 72 kg/fed) with four replicates for each treatment. Irrigation water amounts were calculated according to Penman –Monteith equation. The results were analyzed statistically. The obtained results can be summarized as follows:

The highest deficit level with the minimum fertilizer level (D_3F_1) gave the highest IR value, water saving value and fertilizer efficiency. Using of moderate or high doses of water and fertilizers seems to be unadvisable in spite of getting profitable IR value due to economical aspects.

Increasing soil moisture deficit to D_3 associated with NPK level of F_1 lead to a negative significant relation with actual evapotranspiration and positive significant one with soil temperature. On the other hand, both crop coefficient and soil moisture content show positive significant relation with decreased soil moisture deficit to D_1 with fertilization treatments F_2 and F_1, respectively.

Positive significant increase of water use efficiency with increasing soil moisture deficit to D_3 and with fertilization by F_1 and F_2, respectively.

It is recommend to irrigate at high soil moisture deficit of 60% and use the lowest level of NPK fertilizer (F_1) to obtain the highest water use efficiency, initial and modified investment ratio and irrigation water saving of sunflower for areas have the same conditions as for the studied one.

Keywords: irrigation scheduling, soil moisture deficit, NPK, sunflower.

Sunflower (*Helianthus annus, L.*) is one of the promising oil crops in Egypt, which could help in increasing oil production. Doorenbos and Kassam (1979) reported that, in suitable climates, good seed yields under irrigation are between 2.5 and 3.5 ton/ha (1.05 to 1.47 ton/fed). The water requirements of sunflower vary from 600 to 1000 mm, depending on climate and length of total growing period (140 days). Evapotranspiration increases from establishment to flowering, and can be as high as 12 to 15 mm/day. The crop coefficient (Kc) is 0.3 – 0.4 during the initial stage (20 to 25 days), 0.7 – 0.8 during the crop establishment stage (35 to 40 days), 1.05 – 1.2 during the mid-season stage (40 to 50 days), 0.7 – 0.8 during the late-season stage (25 to 30 days) and 0.4 at maturity or harvest stage. The yield response to water was 0.25, 0.5, 1.0, 0.8 and 0.95 for different stages and seasonally, respectively. They found that irrigating sunflower for high production, soil water depletion should not exceed 45 % of available soil water. They reported that the water utilization efficiency for harvested yield of seeds containing 6 to 10 percent moisture is about 0.3 to 0.5 kg / m^3.

Several investigators found that consumptive use of different crops increased by increasing amount of irrigation water or shortening irrigation intervals, as soil moisture stress decreased. But water use efficiency increased with decreasing the amount of irrigation water and increasing irrigation intervals, (Rizk, 2002; Seidhom *et al.*, 2002 and El-Dosouky *et al.*, 2005).

Barsoum and Salem (1993) stated that P and K treatments had significant positive effect on sunflower plant characters at harvest. Also, increasing rate of P and K with Zn caused significant increases in yield and plant characters at harvest. The highest seed yield/fed was obtained by 60 kg P_2O_5 with 48 kg K_2O as affected by 0.5% Zn. Also, many investigators reported that sunflower seeds yield and its components responded to NPK fertilitizers (Tripathi and Kalra, 1981; El-Sayed *et al.*, 1984 and El-Gayar *et* *al.*, 1990). El-Sersawy *et al.* (1993) found that the yield of sunflower seed was significantly correlated with the improved soil physical and microbioloical properties. Highest production was achieved under soil moisture depletion of 60% and 48 kg P_2O_5 / fed.

However, as soil temperature is considered as one of the important factors as soil water in relation to plant growth it has been included in the work. Khalifa (1992) found that the temperature effects decreased with increasing water content. Persson and Berndtsson (1998) concluded that water content increased with increasing soil temperature and the temperature dependence of the bulk electrical conductivity. Campbell *et al.* (1995) reported that when the soil was initially dry , the temperature increase more rapidly.

The influence of soil moisture deficit, NPK fertilizer levels and their interactions on yield and yield components, soil moisture content, soil temperature, actual evapotranspiration and water use efficiency and crop coefficient of sunflower grown under calcareous soil were investigated. This trial was to get high yields of this summer fodder plant and to detect how to increase its productivity.

MATERIALS AND METHODS

The current work was carried out during summer season of 2003 in the agricultural experimental station of the Desert Research Center at Maryut, Alexandria Governorate, Egypt. The study intends to evaluate the influence of soil moisture deficit, NPK levels and their interaction on the yield and yield components of sunflower. Soil temperature, soil moisture content, actual evapotranspiration and water use efficiency, water saving and crop coefficient of sunflower grown under calcareous soil conditions were investigated. In general, the area is characterized by the Mediterranean climates, which have dry hot summer and relatively cold winter. Meteorological data for about 30 years were collected from the Climatic Atlas of Egypt (1996). Also, meteorological data for the cultivated season were collected from the meteorological station site as altitude, latitude and longitude are about 13 meter a.s.l., 31°22' N and 29°27' E., respectively, to compute potential evapotranspiration (ETo) rates using Penman – Monteith equation (Allen *et al.*, 1998).

The study was conducted in a split-split-plot design with four replicates, including 36 plots. The treatments include three soil moisture deficits from available soil water (D_1 = 30 % , D_2 = 45 % and D_3 = 60 %) converted to irrigation intervals (Dorrenbos and Pruitt, 1977). three levels of NPK fertilizer (F_1: N = 45, P = 45 & K = 24 kg /fed), (F_2: N = 55, P = 60 & K = 48 kg /fed) and (F_3: N = 65, P = 75 & K = 72 kg/fed), with (D_2 F_2 treatment considered as the control in this area). Each plot was 3.0 x 3.5 m with 6 ridges. Sunflower seeds (*C. V. Zhar El-Hayaa*) were sown at a rate of

25 kg/feddan, on May 26 th in 2003 season, 12 plants per ridge, 30 cm apart and 50 cm between the rows. After 25 days from sowing, seedlings were thinned to one plant per pit. The conventional agricultural practices were used for cultivating sunflower plants (24000 plant/fed.).

During the preparation of seed bed superphosphate was applied at the rates of 45, 60 and 75 kg P_2O_5/fed., nitrogen as amonium sulphate (20.6 % N) was added at rates of 45, 55 and 65 kg N/fed in three equal doses after 25, 45, and 60 days from planting, and potassium sulphate (48 % K_2O) at rates of 24, 48 and 72 kg K_2O/fed in two equal doses after 25 and 45 days from planting. Irrigation water amounts calculated according to Penman – Monteith equation.

Some physical and chemical soil characteristics of the studied soil site were determined according to Richards (1954), and the obtained results were recorded in tables (1a and b).

TABLE (1a). Some physical properties of the soil of the experimental site.

Soil depth cm	Particle size distribution %				Texture class	Particle density (g /cm^3)	Bulk density (g/cm^3)	Porosity (%)	Moisture content % (weight basis)		Available soil water		Infiltration rate	
	Coarse sand	Fine sand	Silt	Clay					Field capacity	Wilting point	% (W.)	mm/100 cm	cm/hr	Class
0-20	10	46	20	24	S.C.L.	2.28	1.41	38.16	26.32	13.23	13.09	184.6	4.35	Moderate
20-40	8	47	18	26	S.C.L.	2.26	1.39	38.50	26.61	13.47	13.14	182.6		
40-60	10	48	16	28	S.C.L.	2.25	1.37	39.11	27.23	14.03	13.20	180.8		
60-80	8	48	17	27	S.C.L.	2.30	1.35	41.30	27.43	14.21	13.22	178.5		

S.C.L.: Sandy clay loam

TABLE (1b). Some chemical properties of the soil of the experimental site.

Soil depth cm	$CaCO_3$ %	Organic matter %	pH (soil paste)	E.C dSm^{-1}	Soluble cations (me/l)				Soluble anions (me/l)				CEC me/100g soil	Exchangeable cations (me/100g soil)			
					Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-		Ca^{++}	Mg^{++}	Na^+	K^+
0-20	32	0.65	7.70	5.22	11.17	3.27	10.66	1.03	_	2.61	10.81	12.69	20.06	8.36	2.93	7.35	1.42
20-40	33	0.32	7.90	4.89	10.35	3.18	10.08	0.84	_	2.39	10.34	11.69	19.42	8.13	2.87	7.11	1.31
40-60	32	0.49	7.82	4.76	9.76	2.99	10.11	0.93	_	2.21	9.89	11.71	19.62	7.87	2.90	7.48	1.37
60-80	37	0.58	8.00	5.57	11.37	3.59	11.76	1.11	_	3.63	11.13	13.14	20.24	8.23	2.71	8.07	1.23

pH = soil reaction E.C. = electrical conductivity CEC = cation exchange capacity

The chemical analysis of irrigation water is shown in table (2) and revealed that this water belongs to high salinity, high sodium, i.e., C_4 S_4 water (Richards, 1954).

TABLE (2). Chemical analysis of the irrigation water of Maryut research station.

pH	T.D.S. ppm.	E.C. dS / m	S.A.R	Soluble cations (mq/l)				Soluble anions (mq/l)				Class
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	
7.8	4387	6.85	9.41	12.46	15.76	35.36	0.76	0	19.24	14.50	34.76	C_4S_4

pH = soil reaction E.C. = electrical conductivity T.D.S. = Total dissolved solids
S.A.R = Sodium adsorption ratio mq/l = m equivalent per liter

The amounts of irrigation water were calculated as follows:

D_{iw} = ((ETo x kc x D) + LF)/ Ea (Doorenbos and Pruitt, 1977)

Where:

D_{iw} = Applied irrigation water (mm)

ETo = Potential evapotranspiration (mm/day) using the average of 30 years for the meteorological data collected from the Climatic Atlas of Egypt (1996).

Kc = Crop coefficient from Allen et al. (1998).

L.F = Leaching fraction (assumed 20 %) .

Ea = Irrigation system efficiency (assumed 60 %).

D = Root depth (m).

Irrigation water amounts shown in table (3) were added by surface irrigation method in which the water amounts were controlled by V-notch equipment installed on the water inlet of the main irrigation channel, while both sub-mains and laterals were open ditches.

Three soil moisture deficit from available soil water: D1 = 30 %, D2 = 45 % and D3 = 60 % converted to irrigation intervals by using irrigation scheduling program (Table 3).

i = ((p. Sa) D) / (ETc – Pe) (Doorenbos and Pruitt, 1977).

Where:

i = interval between two irrigations (days).
p = applied fraction of available soil water.
Sa = total available soil water (mm/m).
D = rooting depth, (m)
ETc = (ETo) kc = maximum crop evapotranspiration (mm)
Pe = effective rainfall (mm)

TABLE (3).Irrigation water applied and Irrigation scheduling of sunflower grown at Maryut area.

Sunflower	Planting date (26/5/2003)				Irrigation intervals (days)			Periods	Irrigation water amounts			
Stages	Months	ETo	Kc	Root depth (m)	Deficit 30 %	Deficit 45 %	Deficit 60 %	(days)	m^3/fed / day	m^3 / fed	mm/m /day	mm/m
Initial 20 day	May	6.06	0.30	0.2	6	9	12	5	3.05	15.27	0.73	3.64
	June	6.82	0.40	0.3	6	9	12	15	6.87	103.12	1.64	24.55
Development 35 day	June	6.82	0.75	0.5	5	8	11	15	21.48	322.25	5.12	76.73
	July	6.44	1.00	0.6	5	8	10	20	32.46	649.15	7.73	154.56
Mid. 35 day	July	6.44	1.05	0.7	6	8	11	11	39.76	437.37	9.47	104.13
	Aug.	6.42	1.10	0.8	6	9	12	24	47.46	1138.96	11.30	271.18
Lat. 25 day	Aug.	6.42	0.75	0.9	10	15	20	7	36.40	254.81	8.67	60.67
	Sep.	5.38	0.40	1.0	18	18	18	18	18.08	325.38	4.30	77.47
At harvest	Sep.	-	-	-	-	-	-	12	-	-	-	-
	Oct.	-	-	-	-	-	-	3	-	-	-	-
115 day	Avg.	6.35	0.72	0.63	-	-	-	130	25.70	3246.30	6.12	772.93

Soil temperature was determined before every irrigation at 12 a.m. in various depths: 5, 10 and 15 cm with thermocouple instrument.

To determine water consumption, soil moisture content was gravimetrically determined every irrigation and hence the crop water consumptive use was calculated by the following equation:

$$ETa = (M_{.2}\ \% - M_{.1}\ \%) \times d_b \times D \times 1000$$

(Doorenbos and Pruitt, 1977)

Where:

ETa = actual evapotranspiration (mm).

$M_{.2}$ = Moisture content after irrigation (%).

$M_{.1}$ = Moisture content before irrigation (%).

d_b = Bulk density of soil (g / cm^3)

D = Active root depth (mm).

At harvest, after 130 days from sowing of sunflower plants, the yield, and yield components were recorded and determined.

Water use efficiency as kg/m^3 was calculated by dividing the crop yield by the amount of actual seasonal evapotranspiration (Giriappa, 1983). Crop coefficient was calculated by dividing the actual evapotranspiration (ETa) by potential evapotranspiration (ETo) calculating from meteorological data for the cultivated season (Yaron *et al.* 1973).

Data were subjected to the analysis of variance of the split-split-plot design according to the method described by Snedecor and Cochran (1989).

Investment Ratio (IR) was calculated as the product of dividing outputs by inputs in LE.

RESULTS AND DISCUSSION

Soil Moisture Content

Data presented in table (4) show safe distance of all values away from the wilting point, also the data reveal highly significant effect for soil moisture deficit, NPK levels and their interactions on soil moisture content. So, as soil moisture content increased by decreasing soil moisture deficit, in the order of D_1 (30%) > D_2 (45%) > D_3 (60%) and as fertilization dose increased the soil moisture content decreased in the order of $F_1>F_3>F_2$.

TABLE (4). Average of soil moisture content % before irrigation under sunflower grown in Maryut region.

Treatments		May	June	July	Aug.	Sep.	Oct.	Average of soil moisture content %
Active root depth, cm		20	40	60	60	60	60	
Soil moisture deficit	D1	16.03	17.53	17.90	17.64	18.63	17.72	17.58 a
	D2	14.32	15.97	16.74	16.13	17.76	18.21	16.52 b
	D3	12.89	14.95	15.64	15.08	17.00	18.40	15.66 c
	LSD							0.089 ***
NPK fertilizer	F1	16.43	16.81	17.26	17.16	18.45	18.80	17.49 a
	F2	12.86	15.45	16.24	15.43	17.15	17.55	15.78 c
	F3	13.95	16.20	16.78	16.26	17.80	17.98	16.50 b
	LSD							0.090 ***
D1 = 30%	F1	17.48	18.05	18.15	18.22	19.29	18.70	18.31
	F2	14.98	16.93	17.68	16.94	17.97	16.81	16.89
	F3	15.64	17.60	17.87	17.75	18.64	17.66	17.53
D2 = 45%	F1	16.49	16.78	17.22	17.00	18.25	18.80	17.42
	F2	12.72	15.09	16.19	15.45	17.25	17.83	15.76
	F3	13.76	16.05	16.82	15.94	17.79	18.00	16.39
D3 = 60%	F1	15.33	15.59	16.42	16.25	17.81	18.91	16.72
	F2	10.88	14.32	14.86	13.90	16.23	18.00	14.70
	F3	12.46	14.95	15.66	15.09	16.96	18.28	15.57
LSD Interaction between D and F								0.052 **

a, b, c, letters indicated to significant differences between treatments.
** = significant at 0.01 *** = significant at 0.001

Concerning the interaction effect, the highest soil moisture content was obtained by adding N = 45, P = 45 & K = 24 (F_1) unit under irrigation water at low soil moisture deficit of 30% (D_1).

However, the effect of both treatments; i.e. moisture deficit and fertilization level, are quite contra verse, so as both soil moisture deficit and fertilization levels increased more dryness before irrigation could be achieved. This could be explained by the apparently active plant growth due to fertilization did not accompanied by needed water so soil moisture content decreased under these conditions.

Similar results were obtained by Khalifa (1992), Barsoum and Salem (1993), El-Sersawy *et al.* (1993), Campbell *et al.* (1995) and Persson and Berndtsson (1998).

Soil Temperature

Instantly, it is important to note that the difference in soil temperature by ± 1 °C is equal to ± 237 Mega cal / fed to 20 cm depth for soil having 1.41 g/cm^3 bulk density and 0.2 cal / g heat capacity.

Data presented in table (5) show that variations for soil temperature extends from top to 15 cm. depth, this, in fact give impression for success of treatments in harmonizing soil moisture so soil temperature as well. Data also reveal that highly significant effect and significant differences between both individual soil moisture deficits, NP cm K levels and their interactions with soil temperature at all depths (0-5 cm), (5-10 cm) and (10-15 cm). So, soil temperature increased by increasing soil moisture deficit, in the order of D_3 (60%) > D_2 (45%) > D_1 (30%), but no significant difference between D_1 and D_2. Regarding the effect of NPK levels on soil temperature, it was in the order of F_1>F_3>F_2, with significant differences between F_1 and F_2 only. Concerning the interaction effect, the highest soil temperature was observed with F_1 under 60% soil moisture deficit (D_3).

TABLE (5). Soil temperature (°C) at different depths before irrigation under sunflower grown at Maryut region.

Treatments		Soil temperature °C at 5 cm depth							Soil temperature °C at 10 cm depth							Soil temperature °C at 15 cm depth						
Moisture deficit	NPK fertilizer	May	Jun	Jul	Aug	Sep	Oct	Season	May	Jun	Jul	Aug	Sep	Oct	Season	May	Jun	Jul	Aug	Sep	Oct	Season
Soil moisture deficit	D1	27.21	27.16	28.87	28.89	28.43	28.15	28.12 b	26.71	26.80	27.85	28.23	27.90	27.62	27.52 b	25.43	25.52	26.31	27.12	26.57	26.31	26.21 b
	D2	27.74	27.71	29.87	29.07	28.67	28.38	28.57 b	27.22	27.16	28.50	28.50	28.13	27.85	27.89 b	25.92	25.87	26.49	27.38	26.79	26.52	26.50 b
	D3	28.36	29.68	29.89	29.84	29.52	29.23	29.42 a	27.83	28.14	28.74	29.24	28.97	28.68	28.60 a	26.51	26.80	27.63	28.06	27.59	27.31	27.31 a
LSD								0.53**							0.63 *							0.39**
NPK fertilizer	F1	28.09	28.13	29.87	29.50	29.22	28.93	28.96 a	27.57	27.38	28.46	28.93	28.68	28.39	28.24 a	26.25	26.08	26.88	27.75	27.31	27.04	26.89 a
	F2	27.46	28.12	29.34	28.98	28.55	28.26	28.45 b	26.95	27.29	28.25	28.38	28.01	27.73	27.77 b	25.66	25.99	26.71	27.29	26.68	26.41	26.46 b
	F3	27.76	28.29	29.41	29.31	28.85	28.56	28.70ab	27.24	27.43	28.39	28.66	28.31	28.03	28.01ab	25.94	26.12	26.83	27.51	26.96	26.69	26.68ab
LSD								0.39 *							0.28 *							0.23**
D1 = 30%	F1	27.60	27.20	29.02	29.03	28.64	28.35	28.31	27.09	26.94	27.92	28.42	28.10	27.82	27.71	25.80	25.66	26.45	27.22	26.76	26.49	26.40
	F2	26.86	27.04	28.70	28.80	28.23	27.95	27.93	26.36	26.66	27.66	28.05	27.70	27.43	27.31	25.10	25.39	26.18	27.01	26.38	26.12	26.03
	F3	27.18	27.22	28.91	28.84	28.44	28.15	28.12	26.67	26.79	27.99	28.23	27.90	27.62	27.53	25.40	25.51	26.30	27.12	26.58	26.31	26.20
D2 = 45%	F1	28.13	27.85	29.80	29.45	29.11	28.82	28.86	27.60	27.52	28.59	28.93	28.56	28.28	28.25	26.29	26.21	27.03	27.76	27.20	26.93	26.90
	F2	27.33	27.44	29.93	28.66	28.30	28.02	28.28	26.82	26.84	28.48	28.15	27.77	27.49	27.59	25.54	25.56	26.10	27.11	26.45	26.18	26.16
	F3	27.75	27.83	29.88	29.10	28.59	28.31	28.58	27.23	27.12	28.43	28.41	28.06	27.78	27.84	25.94	25.83	26.35	27.27	26.72	26.46	26.43
D3 = 60%	F1	28.54	29.35	30.80	30.03	29.93	29.63	29.71	28.01	27.68	28.87	29.45	29.37	29.08	28.74	26.68	26.36	27.18	28.26	27.97	27.69	27.36
	F2	28.19	29.86	29.41	29.49	29.11	28.81	29.15	27.66	28.37	28.62	28.95	28.56	28.28	28.41	26.35	27.01	27.85	27.76	27.20	26.93	27.18
	F3	28.35	29.81	29.46	29.99	29.53	29.23	29.40	27.82	28.37	28.74	29.32	28.98	28.69	28.65	26.50	27.01	27.85	28.16	27.60	27.32	27.41
LSD Interaction								0.22 *							0.16 *							0.13 *

a, b, c, letters indicated to significant differences between treatments.

LSD Interaction between D and F * = significant at 0.05 ** = significant at 0.01

These findings may be due to decreasing evaporation which enhancing soil water storage, thereby increasing chemical and biological processes. All these processes will increase soil temperature, so changing the energy balance towards maintaining sufficient heat energy for growth processes. Generally, soil temperature decreases gently with increasing soil depth. Increasing salinity lead to increasing heat energy which consumped in water movement and damping the moisture movement. Similar results were obtained by El-Nawawy (1986), Khalifa (1992), El-Sersawy *et al.* (1993), Campbell *et al.* (1995) and Persson and Berndtsson (1998).

Yield And Yield Components

Concerning the effect of soil moisture deficit on growth parameters, yield and yield components of sunflower plants, data in table (6) show highly significant effect for total fresh yield, straw yield, oil content % , head seed weight, head weight, 100-seed weight, seed yield, biological yield/plant and oil yield. In brief, growth parameters, yield and yield components for sunflower plants increased by increasing soil moisture deficit, the common magnitude of soil moisture deficit are in order of D3 (60%) > D2 (45%) > D1 (30%).

Regarding the effect of NPK levels on growth parameters and the yield and yield components of sunflower, data in table (6) show significant effect for all crop characteristics, yield and yield components and head seed weight. The effect of NPK on fresh yield, straw yield and biological yield/plant can be arranged in the order of F3>F2>F1. In brief, the highest value were commonly associated with high soil moisture deficit (D_3=60%) under applying N = 65, P = 75 and K = 72 kg/fed.

TABLE (6). Yield and yield components of sunflower grown in Maryut region.

Treatments		Head weight, gm	100-seed weight, gm	Yield / plant, gm	Head seed weight, gm	Oil % .	Oil yield, kg/fed	Total yield, ton/fed	Seed yield, ton/fed	Straw yield, ton/fed
Soil moisture deficit	D1	646.00 b	7.73 b	214.67b	153.00 c	30.79 c	291.32 b	3.810 b	0.946 b	2.864 b
	D2	675.75 b	8.77ab	252.00 a	169.33 b	31.67 b	326.48ab	4.448 a	1.031 ab	3.417 a
	D3	746.33 a	9.89 a	270.75 a	183.00 a	32.53 a	360.84 a	4.775 a	1.108 a	3.668 a
	LSD	44.58**	1.17 *	35.31 *	8.63***	0.73 **	37.48 *	0.475**	0.098 *	0.416 **
NPK fertilizer	F1	628.00 b	8.19 b	230.50 b	165.83 a	31.25 c	305.07 b	4.157 b	0.976 b	3.181 c
	F2	725.25 a	9.24 a	248.58 a	171.08 a	32.09 a	353.70 a	4.402 a	1.099 a	3.302 b
	F3	714.83 a	8.96 a	258.33 a	168.42 a	31.64 b	319.87 b	4.475 a	1.010 b	3.465 a
	LSD	40.52***	0.53**	14.41**	11.26 ns	0.31***	20.51***	0.131***	0.062**	0.118***
D1 = 30%	F1	590.50	7.12	194.50	149.25	30.40	281.02	3.671	0.925	2.746
	F2	677.00	8.24	216.25	159.00	31.08	302.61	3.800	0.974	2.826
	F3	670.50	7.84	233.25	150.75	30.90	290.34	3.958	0.940	3.018
D2 = 45%	F1	633.00	8.09	245.50	168.50	31.25	307.76	4.230	0.986	3.245
	F2	704.50	9.17	251.00	166.75	32.10	359.69	4.539	1.122	3.417
	F3	689.75	9.04	259.50	172.75	31.65	311.98	4.576	0.987	3.590
D3 = 60%	F1	660.50	9.35	251.50	179.75	32.10	326.44	4.570	1.018	3.553
	F2	794.25	10.32	278.50	187.50	33.10	398.80	4.866	1.202	3.664
	F3	784.25	10.00	282.25	181.75	32.38	357.29	4.890	1.103	3.787
LSD Interaction between D and F		23.39*	0.31*	8.32*	0.503*	0.191*	11.84*	0.075*	0.033*	0.068*

a, b, c, letters indicated to significant differences between treatments.

ns = non significant * = significant at 0.05 ** = significant at 0.01

*** = significant at 0.001

On the other hand, the effect of NPK on 100-seed weight, seed yield, oil % , oil yield, head seed weight and head weight are in the order of F2>F3>F1. The highest value are obtained under high soil moisture deficit (D_3=60%) and applying NPK at rates of 55, 60 and 48 kg/fed, respectively. The significant differences were existed between F_1 in one side and F_2 and F_3

on the other one, while almost significant differences between F_2 and F_3 exist. This may be due to the high basic nutritional requirements of this crop.

For convenience, significant interaction effect and significant differences has been found for the interaction between soil moisture deficit, and NPK levels on the yield and yield components of sunflower plants.

For instance, the data in table (6) show somehow untraditional relation between crop yield and soil moisture level as many investigators agreed with the importance of avoiding sharp dryness of calcareous soils due to consistency and nutrients immobilization problems of such soils under dry conditions (El-Gayar *et al.*, 1990 ; Khalifa, 1992 and Barsoum and Salem, 1993). The data reveal significant differences between D_3 treatment in one side with D_1 and D_2 on the other, while insignificant between D_1 and D_2.

These increases with increasing soil moisture deficit could be attributed to the partial aeration increment in the upper part of the root zone, which is essential to crop growth. Also, the excess wetting of the topsoil may have resulted in leaching out of some nutrients from the root zone. One of the expected reasons for increasing yield with increasing soil moisture deficit is the ability of $CaCO_3$ to dissolve with increasing salinity in irrigation water, so it has a buffering action under these conditions especially with the sensible amount of organic matter the soil depth table (1 b), El-Nawawy (1986). This also attributed with damping the water movement, which maintain favorite conditions to soil solution adsorption. These results were similar to those reported by Barsoum and Salem (1993) and El-Sersawy *et al.* (1993).

Actual Evapotranspiration (ETa)

Data presented in table (7) reveal highly significant effect of soil moisture deficit, NPK levels and their interactions on actual evapotranspiration of sunflower plants. Actual evapotranspiration decreased by increasing soil moisture deficit, in the order of $D_1 > D_2 > D_3$.

Regarding the effect of NPK levels on ETa, the values are in the order of $F_2 > F_3 > F_1$, with highly significant differences among them. However, the highest resulted value has been recorded for D_1 F_2 treatment. However, referring to table (6) it can be noticed that there is a good relation between crop components especially these concerning oil yield and F_2 level, which may indicate favorable nutritional conditions compared to F_1 and F_3 levels.

Concerning the interaction effect, the lowest actual evapotranspiration observed by adding F_1 under irrigation water at high soil moisture deficit of 60% with highly significant interaction effect.

TABLE (7). Monthly actual evapotranspiration (m^3/fed) of sunflower grown in Maryut region.

Treatments		May	Jun.	Jul.	Aug.	Sep.	Oct.	ETa m^3/fed	ETa mm/day	ETa mm/season
Soil moisture deficit	D1	46.58	386.88	640.00	435.06	233.79	21.87	1764.18	2.86 a	420.04
	D2	41.99	377.31	554.72	424.71	231.40	18.50	1648.63	2.64 b	392.53
	D3	38.36	341.59	510.32	388.58	191.84	17.21	1487.89	2.39 c	354.26
	LSD							20.123	***	
NPK fertilizer	F1	29.17	315.69	504.33	338.19	170.86	14.43	1372.67	2.14 c	326.83
	F2	52.30	426.07	634.07	493.72	267.37	23.08	1896.62	3.08 a	451.58
	F3	45.45	364.01	566.63	416.44	218.80	20.07	1631.41	2.66 b	388.43
	LSD							26.340	***	
D1 = 30%	F1	32.73	326.40	586.88	357.20	165.56	15.14	1483.91	2.32	353.31
	F2	56.67	455.30	686.87	528.09	302.78	28.18	2057.89	3.38	489.97
	F3	50.34	378.95	646.25	419.90	233.04	22.28	1750.74	2.87	416.84
D2 = 45%	F1	28.13	315.63	491.18	347.24	195.24	14.46	1391.88	2.16	331.40
	F2	52.23	444.72	628.28	485.32	269.51	21.13	1901.19	3.06	452.66
	F3	45.61	371.57	544.69	441.57	229.45	19.92	1652.82	2.68	393.53
D3 = 60%	F1	26.65	305.05	434.93	310.14	151.77	13.68	1242.22	1.95	295.77
	F2	48.01	378.19	587.07	467.74	229.82	19.94	1730.77	2.80	412.09
	F3	40.41	341.52	508.95	387.87	193.91	18.01	1490.68	2.42	354.92
LSD Interaction between D and F								15.21	***	

a, b, c, letters indicated to significant differences between treatments.
*** = significant at 0.001

This trend due to the amount of water available to plants in addition to the higher evaporation from the wet rather than dry soil surface and to the higher transpiration from plants as well as the amount of water needed for plant growth, development and building of plant tissues and organs. Similar results were obtained by Barsoum and Salem (1993), El-Sersawy *et al.* (1993) and Rizk, (2002).

Water Saving

The modified amounts of irrigation water were calculated as follows:

D_{iw} = (ETa + LF) / Ea (Doorenbos and Pruitt, 1977)

Where:

D_{iw} = Applied irrigation water (mm)
ETa = actual evapotranspiration (mm/day)
L.F. = Leaching fraction (assumed 20 %) .
Ea = Irrigation system efficiency (assumed 60 %).

From the data of actual evapotranspiration, table (7) it is clear that there are some treatments giving water saving values for the applied water for irrigation purpose, while the rest give higher consumption values than applied. The achieved values for water saving differ greatly among treatments which ranged between 264.94 as minimum and 761.87 m^3/fed as maximum (Table 8).

TABLE (8). Water loss (-) or water gain (+) of sunflower crop grown in Maryut region.

Moisture deficit	NPK fertilizer	Irrigation water applied m^3/fed	actual evapotranspiration m^3/fed	Modified irrigation water m^3/fed	Water loss (-) or water gain (+) m^3/fed
D1 = 30%	F1	3246.30	1483.91	2967.83	+278.47
	F2	3246.30	2057.89	4115.78	-869.48
	F3	3246.30	1750.74	3501.49	-255.19
Average		3246.30	1764.18	3528.37	-282.07
D2 = 45%	F1	3246.30	1391.88	2783.76	+462.54
	F2	3246.30	1901.19	3802.38	-556.08
	F3	3246.30	1652.82	3305.64	-59.34
Average		3246.30	1648.63	3297.26	-50.96
D3 = 60%	F1	3246.30	1242.22	2484.43	+761.87
	F2	3246.30	1730.77	3461.55	-215.25
	F3	3246.30	1490.68	2981.36	+264.94
Average		3246.30	1487.89	2975.78	+270.52

Generally, F_1 treatment indicates sensible water saving values which increased with increasing deficit level from D_1 to D_3, while F_2 coincides with clear high water consumption (which could be compensated by the near sub-surface water level) which decreased gradually with increasing deficit level from D_1 to D_3. F_3 treatment indicate special trend as it translocation from over using for D_1 and D_2 to water saving with D_3. Meanwhile, the amount of water that has been saved in each treatment expected to accumulate along the growth period by a manner, which could deviate the deficit level from the applied limit.

Water Use Efficiency of Sunflower (W.U.E.)

Data presented in table (9) reveal highly significant effect and significant differences for both solely soil moisture deficit, NPK levels and their interactions on water use efficiency of sunflower plants. However, water use efficiency of seeds, oil and yield of sunflower increased by increasing soil moisture deficit, in the order of $D_3 > D_2 > D_1$. While for NPK levels, the values in the order of $F_1>F_3>F_2$ with few exceptions for F_1 and F_2 values for seed and oil.

Concerning the highest water use efficiency value it was obtained by adding F_1 level under irrigation with the highest soil moisture deficit of 60% (D_3).

This increase in W.U.E. is due to: a) the decrease of actual evapotranspiration at high soil moisture deficit (D_3) and, b) the correspondent high yield. So, it is suggested that these practices activate both water and nutrient consumptions by roots of plants which increased crop yield, thus increased W.U.E. These findings are in harmony with Barsoum and Salem (1993), El-Sersawy *et al.* (1993), Rizk (2002), Seidhom *et al.* (2002) and El-Dosouky *et al.* (2005).

TABLE (9). Water use efficiency (kg/m^3) of sunflower grown in Maryut region.

Treatments		Oil	Seed	Total yield
Soil moisture deficit	D1	0.165 c	0.536 c	2.159 c
	D2	0.198 b	0.625 b	2.698 b
	D3	0.243 a	0.744 a	3.210 a
	LSD	0.021***	0.057***	0.325***
NPK fertilizer	F1	0.224 a	0.717 a	3.064 a
	F2	0.189 b	0.586 b	2.348 c
	F3	0.198 b	0.625 b	2.770 b
	LSD	0.013***	0.041***	0.08***
D1 = 30%	F1	0.189	0.623	2.474
	F2	0.147	0.473	1.847
	F3	0.166	0.537	2.261
D2 = 45%	F1	0.221	0.708	3.039
	F2	0.189	0.590	2.387
	F3	0.189	0.597	2.769
D3 = 60%	F1	0.263	0.819	3.679
	F2	0.230	0.695	2.811
	F3	0.240	0.740	3.280
LSD Interaction between D and F		0.007***	0.022**	0.041***

a, b, c, letters indicated to significant differences between treatments. *** = significant at 0.001

For instance, water use efficiency is an absolute value that means it is not dependant on any economic values, such as yields prices and irrigation costs. So, the most beneficial use of this value is a comparative value for the better options for using water, especially when water suffer from shortage, to produce a group of crops under certain conditions. However, the investment ratio (IR) may be more reliable in verifying the economics of producing any certain crop.

Economical Assessment

The economical evaluation of the experimental findings in any research is of a great importance depending on the net return of such treatments, which could encourage the farmer to use, or not. The values of investment ratio (IR) are illustrated in table (10). From the table it is clear that using the combination of irrigates at the best treatment of soil moisture deficit (60%) and adds F1 levels of NPK fertilizer (N = 55, P = 60 & K = 48 kg/fed) gave the best values of I R of sunflower crop.

TABLE (10). Initial and modified inputs, outputs items and investment ratio (IR) of sunflower yield grown in Maryut region.

Economical item	Soil management	D1			D2			D3		
		F1	F2	F3	F1	F2	F3	F1	F2	F3
List of input, LE/feds	land preparation, LE/fed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Seeds, LE/fed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Cultivation, LE/fed	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
	Irrigation, LE/fed	811.5	811.5	811.5	811.5	811.5	811.5	811.5	811.5	811.5
	Modified irrigation, LE/fed	742.0	1028.9	875.4	695.9	950.6	826.4	621.1	865.4	745.3
	Irrigation labors costs, LE/fed	540.0	540.0	540.0	360.0	360.0	360.0	300.0	300.0	300.0
	Mineral fertilizer, LE/fed	150.0	180.0	210.0	150.0	180.0	210.0	150.0	180.0	210.0
	Fertilizer labors costs, LE/fed	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	Pest control, LE/fed	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	Weed control, LE/fed	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	Machines, LE/fed	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0
	Fuel, LE/fed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Harvesting, LE/fed	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
	Crop transport, LE/fed	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	Rent (on season), LE/fed	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Total input, LE/fed	2531.5	2561.5	2591.5	2351.5	2381.5	2411.5	2291.5	2321.5	2351.5
	Modified total Input, LE/fed	2462.0	2778.9	2655.4	2235.9	2520.6	2426.4	2101.1	2375.4	2285.3
List of outputs	Yield, kg/fed	3671.0	3800.0	3958.0	4230.0	4539.0	4576.0	4570.0	4866.0	4890.0
	Price, LE/kg	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Total price, LE/fed	3487.5	3610.0	3760.1	4018.5	4312.1	4347.2	4341.5	4622.7	4645.5
	Net income, LE/fed	956.0	1048.5	1168.6	1667.0	1930.6	1935.7	2050.0	2301.2	2294.0
	Modified net Income, LE/fed	1025.5	831.1	1104.7	1782.6	1791.5	1920.8	2240.4	2247.3	2360.2
Investment ratio, LE/ILE		1.38	1.41	1.45	1.71	1.81	1.80	1.89	1.99	1.98
Modified investment ratio, LE/ILE		1.42	1.30	1.42	1.80	1.71	1.79	2.07	1.95	2.03

The IR values calculated two times, table (10) as one for the planned amount of irrigation water, while the other with actually consumed amounts. So, the result and IR values can be discussed as follows:

Although all treatments gave IR values exceed the national rate (1.25), yet selecting appropriate treatments can be based on some economical aspects as water saving referring to the scarcity of water resources in such location, minimum fertilization referring to the global interest toward minimizing the uses of agrochemical so, maximizing the net return of currency unit (LE). Therefore, the recommended treatments can be arranged in ascending order as $D_1F_2 < D_1F_1$, $D_1F_3 < D_2F_2 < D_2F_1$, $D_2F_3 < D_3F_2 < D_3F_1$, D_3F_3 . From this order it can be conclude the following that the highest deficit level (D_3 = 60% = 10 irrigation times, table 3) gave the highest IR values among all treatments especially with minimum fertilization dose (F_1), so this treatment D_3F_1 achieve all environmental needs which stated before.

On the other hand more fertilization application (D_3F_2 and D_3F_3) contribute with:

1- Smaller IR value (in spite of exceeding national IR rate).
2- More hazardous effects expected from agrochemical uses.
3- Small water saving or even more consumption of water without relative net achieved profit.

The highest water application rate (D_1 = 30% = 18 irrigation times) coincides with the lowest IR values even with high fertilization levels (F_2 and F_3), which contribute to actual overuse watering.

The moderate deficit level (D_2 = 45% = 12 irrigation times) contributes to moderate IR values. However, the lowest fertilization level (F_1) it gives the highest IR value and amount of water that saved along the experiment time, while other two levels (F_2 and F_3) coincide with overusing of water. In all cases, as mentioned before, these overused amounts may be derived from the near sub-surface water table.

Crop Coefficient (Kc) of Sunflower

Data presented in table (11) reveal that highly significant effect of soil moisture deficit, NPK levels and their interactions on crop coefficient of sunflower plants. Crop coefficient of sunflower increased by decreasing soil moisture deficit, the magnitude are in order of $D_1 > D_2 > D_3$.

Regarding the effect of NPK on crop coefficient of sunflower, the highest values corresponding by the second level (F_2) of NPK and the lowest values corresponding by the first level (F_1), the magnitude are in order of $F_2>F_3>F_1$.

TABLE (11). Crop coefficient (Kc) of sunflower grown in Maryut region.

Treatments		May	June	July	Aug.	Sep.	Oct.	Season Kc
Soil moisture deficit	D1	0.37	0.45	0.76	0.52	0.34	0.43	0.48 a
	D2	0.33	0.44	0.66	0.51	0.34	0.36	0.44 b
	D3	0.30	0.40	0.61	0.46	0.28	0.34	0.40 c
	LSD							0.005***
NPK fertilizer	F1	0.23	0.37	0.60	0.40	0.25	0.28	0.36 c
	F2	0.41	0.50	0.76	0.59	0.39	0.45	0.52 a
	F3	0.36	0.42	0.67	0.50	0.32	0.39	0.44 b
	LSD							0.007***
D1 = 30%	F1	0.26	0.38	0.70	0.43	0.24	0.30	0.38
	F2	0.45	0.53	0.82	0.63	0.45	0.55	0.57
	F3	0.40	0.44	0.77	0.50	0.34	0.44	0.48
D2 = 45%	F1	0.22	0.37	0.58	0.42	0.29	0.28	0.36
	F2	0.41	0.52	0.75	0.58	0.40	0.41	0.51
	F3	0.36	0.43	0.65	0.53	0.34	0.39	0.45
D3 = 60%	F1	0.21	0.35	0.52	0.37	0.22	0.27	0.32
	F2	0.38	0.44	0.70	0.56	0.34	0.39	0.47
	F3	0.32	0.40	0.61	0.46	0.29	0.35	0.40
LSD Interaction between D and F								0.01 ***

a, b, c, letters indicated to significant differences between treatments. *** = significant at 0.001

Concerning the interaction effect, the highest crop coefficient of sunflower was obtained by adding (F_2) under irrigation lowest soil moisture deficit 30%. This may be due to increasing the exposed water surface for evaporation as the soil catches more water much longer time thus increasing actual evaporation and crop coefficient. Also, increasing salinity lead to $CaCO_3$ solution which damping of water movement and buffering action for nutrients and salinity (El-Nawawy, 1986). These findings agreed with Allen *et al.* (1998), Seidhom *et al.* (2002) and El-Dosouky *et al.* (2005).

CONCLUSION

It is suggested to irrigate at high soil moisture deficit 60% and use the lowest level of NPK fertilizer F_1 to obtain the highest water use efficiency, initial and modified investment ratio (1.89 and 2.32 LE/ investment LE) and irrigation water saving (1681 m^3/fed.) of sunflower at the same conditions these should be carefully evaluated to the studied area.

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تأثير النقص الرطوبى والتسميد على محصول عباد الشمس المنزرع تحت ظروف التربة الجيرية.

سامى حنا سيدهم
قسم كيمياء وطبيعة الأراضي - مركز بحوث الصحراء - المطرية - القاهرة - مصر.

تهدف هذه الدراسة الى تقييم تأثير مستويات النقص الرطوبى من الماء الميسر ومستويات التسميد المعدنى المختلفة على محصول عباد الشمس وعلى الاستهلاك المائى وكفاءة استخدام المحصول للمياه واقتصادياتها وعلى رطوبة وحرارة التربة وترشيد استهلاك مياه الرى من خلال إدارة مائية سليمة بجدولة الرى خلال المراحل المختلفة لنمو النبات تحت ظروف الأراضي الجيرية لترشيد استهلاك مياه الرى ورفع كفاءة استخدام المحصول للمياه.

لهذا الغرض أقيمت تجربة حقلية بمزرعة محطة بحوث مريوط بالعامرية بمحافظة الإسكندرية خلال الموسم الصيفى ٢٠٠٣ تضمنت ٣٦ وحدة تجريبية (٣x ٣,٥ م) من خلال تصميم قطع منشقة مرتين مع الرى بكمية مياه رى محسوبة طبقا إلى معادلة بنمان-مونتيث وإضافة جرعات سمادية معدنية (نيتروجين ، فوسفور ، بوتاسيوم) مناسبة حيث خضعت التجربة للمعاملات التالية:

١- ثلاث مستويات نقص رطوبى من الماء الميسر: (٣٠ % ، ٤٥ % ، ٦٠ %).
٢- ثلاث مستويات تسميد معدنى ن ، فو ، بو كجم / فدان : مستوى تسميد أول (ن = ٤٥ ، فو٢أ٥ =٤٥ ، بو٢أ =٢٤) ، مستوى تسميد ثانى (ن = ٥٥ ، فو٢أ٥ =٦٠ ، بو٢أ =٤٨) ، مستوى تسميد ثالث (ن = ٦٥ ، فو٢أ٥ =٧٥ ، بو٢أ =٧٢)
٣- أربعة مكررات لكل معاملة .

وكانت النتائج كما يلى:

ارتبط أعلى محصول ومكوناته (المحصول الكلى ومحصول البذور ومحصول القش ومحصول الزيت والنسبة المئوية للزيت ووزن النبات ووزن ١٠٠ حبة ووزن بذور القرص ووزن القرص) بالرى عند مستوى نقص رطوبى ٦٠ % أى بزيادة فترة الرى وكانت الفروق معنوية ، كما زاد النمو الخضرى زيادة معنوية بزيادة مستوى التسميد الى مستوى التسميد الثالث حيث زاد كل من المحصول الكلى ومحصول القش ووزن النبات ، بينما أعطى محصول البذور ومحصول الزيت وباقى مكونات نمو المحصول زيادة معنوية مع مستوى التسميد الثانى ، وكانت أقل القيم مع مستوى التسميد الأدنى، وكان هناك تأثير معنوى للتفاعل بين مستويات النقص الرطوبى ومستويات التسميد.

وقد أوضحت الدراسة أن الاستهلاك المائى الفعلي قد قل معنويا ، بينما زاد محتوى حرارة التربة معنويا بزيادة مستوى النقص الرطوبى الى ٦٠ % وبنقص مستوى التسميد الى مستوى التسميد الأول ، بينما زاد معنويا كل من معامل المحصول ومحتوى رطوبة التربة بقلة مستوى النقص الرطوبى الى ٣٠ % وبالتسميد بالمستوى الثاني و الأول على الترتيب ، وكان هناك زيادة معنوية لكفاءة استخدام المحصول للمياه بالتسميد بالمستوى الأول وبزيادة مستوى النقص الرطوبى الى ٦٠ % لكل منهما.

لذلك ينصح بالرى عند مستوى نقص رطوبى ٦٠ % من ماء التربة الميسر والتسميد بأقل كمية سماد معدنى (مستوى التسميد الأول) للحصول على أعلى قيم لكفاءة استخدام المحصول للمياه ولمعامل الاستثمار الابتدائي والمعدل (١,٨٩ ، و ٢,٣٢ جنيه/جنيه مستثمر على الترتيب) ، وترشيد مياه الرى بحوالى ١٨٦١ م^{٣}/فدان وذلك تحت الظروف المشابهة لمنطقة الدراسة فى الأراضي الجيرية.