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EVALUATING WATER PRODUCTIVITY OF SUNFLOWER CROP UNDER DIFFERENT LOCATIONS IN EGYPT

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ABSTRACT: *The present trial was conducted through 2014 in order to determine the impacts of sowing dates and irrigation intervals on sunflower seed production under different Egyptian locations. Seed productivity, crop water use and water productivity (WP) were considered in order to determine the most proper circumstances producing the reasonable seed yield per a unit of water use. The most important findings could be summarized as follows: -*

- *Sunflower seed productivity was significantly differed due to the chosen locations, and higher figures (833.00 and 829.33 kgfad^{-1}) were noticed under Gemmeiza and Giza conditions, respectively. Higher water use was recorded under Shandweel condition (484.4mm). On the contrary, lower water use (415.1 mm) was obtained under Fayoum conditions, which could be attributed to lower seed yield. Crop water use under Sakha, Gemmeiza and Giza conditions did not greatly differ and comprised 406.6, 423.0 and 449.6 mm, respectively. Higher WP values were observed under Gemmeiza, Giza and Sakha conditions which amounted to 0.46, 0.43 and 0.42 kgm^{-3}, respectively. Nevertheless, under Fayoum and Shandweel conditions lower WP values were noticed and comprised 0.32 and 0.36 kgm^{-3}, respectively.*
- *Summer growing season exhibited the highest figure of sunflower seed yield which reached to 1050.94 kgfad^{-1} and exceeded those of Nili and winter growing seasons by 49.68 and 120.6%, respectively. Furthermore, the highest sunflower ET (509.3 mm) and WP values were recorded with summer season. Such findings indicating that the prevailing weather conditions during the summer season were encouraging proper crop performance.*
- *Medium irrigation interval surpassed both short and long irrigation intervals and seed yield increased by 14.84 and 26.39%, respectively. However, the highest water use (ETc) and WP i.e. 478.5 mm and 0.43 kg seeds m^{-3}, respectively, resulted from irrigating at the short interval.*

Key words: *Sunflower seed yield, growing season, irrigation intervals, Water productivity*

INTRODUCTION

Variations in the prevailing soil and climatic environments of the different seasons of sowing are characterized by differences in evaporative demand, temperatures, radiation and precipitation which indubitably affect the crop performance, FAO, 2013. Most of the consumption of irrigation water corresponds to crop evapotranspiration (ET), the loss of water is due to the combined processes of evaporation and transpiration. This understanding is important in the prediction of environmentally derived variation in adaptation and coping strategies in plants under variable growing environmental conditions and as basis for selection of crops. Widely spaced sowing dates provide differences in soil water, temperature and radiation regimes these factors are further compounded by differences in vapour pressure deficits in the different seasons of planting, Agele, 2003).

In Egypt, sunflower seed production reached 24.4 tons produced from 9000 ha, (FAOSTAT, 2013). Great interest must be given towards this crop to decrease edible oil production – consumption gap. Increasing the crop production per unit both of area and water are a very important concern and could be achieved through improving agriculture practices including high yielding varieties, proper sowing date, best irrigation and fertilization management, ..., etc. In this respect, Attia *et al.* (1990) at Nubaria area found that irrigation at 75% ASMD significantly decreased sunflower seed yield by 43.5%, compared to irrigation at 25% ASMD. However, ET_C was increased from 1611.5 to 1748.5 and 1824.1 m^3 fed^{-1}, as the ASMD decreased from 75% to 50% and 25%, respectively. Abdou *et al.* (2011) and Ashry *et al.* (2013) at Fayoum district reported that the highest irrigation level i.e. 1.2 of Cumulative Pan Evaporation norms (C.P.E.), gave the highest values of seed yield, seasonal ET_C and WUE. In same district, Youssef et al. (2014) stated that increasing seasonal applied water quantity to sunflower significantly increased seed yield. In addition, the highest water use and WUE figures were recorded with the highest level of seasonal applied water (2800 $m^3 fad^{-1}$). EL-Sharaihy et al. (2013) at Gemmeiza found that the sunflower seed yield potential reached to 810.47 kg fad^{-1}, which was resulted due to irrigating at 14 days interval as comparing to 21 and 28 days.

The present study aims to determine the impacts of sowing dates and irrigation intervals under different Egyptian locations on the performance of sunflower crop. Seed yield, crop water use and water productivity were considered in order to determine the most proper circumstances resulting in the reasonable seed yield due to the unity of water use.

MATERIALS AND METHODS

The present research trials were conducted during 2014 to determine how growing season and irrigation interval could affect water productivity of sunflower *(Helianthus annuus, var. Sakha 53)* grown at different locations in Egypt. The adopted treatments were executed at the following zones: -

1-North Nile Delta district, Sakha Agric. Res. Station farm (Lat. 31.07 Long. 30.57)
2-Middle Nile Delta district, Gemmeiza Agric. Res. Station farm (Lat. 30.47 Long. 31.0)
3-Middle Egypt district, Giza Agric. Res. Station farm (Lat. 30.03 Long. 31.13)
4-Middle Egypt district, Fayoum Agric. Res. Station farm (Lat. 29.18 Long. 30.51)
5-Upper Egypt district, Shandweel Agric. Res. Station farm (Lat. 26.36 Long. 31.38)

Some soil moisture constants and bulk density values are shown in Table 1, and weather data of the experimental sites at different locations are shown in Table 2.

Table 1: Average of some soil moisture constants and bulk density values for the experimental sites at different locations (mean of 60 cm soil depth).

Locations	Field capacity (%, wt/wt)	Wilting point (%, wt/wt)	Available Moisture (%, wt/wt)	Bulk density (gcm^{-3})	Total available moisture (mm)
Sakha	40.52	22.41	18.46	1.31	145.1
Gemmeiza	39.97	21.71	18.27	1.25	138.5
Giza	32.98	17.38	15.60	1.23	115.1
Fayoum	38.00	18.09	19.91	1.39	166.0
Shandweel	33.77	13.90	19.85	1.22	145.3

Table 2: Weather data of the experimental sites at different locations in 2014.

Locations	Climatic element*	January	February	March	April	May	June	July	August	September	October	November	December
Sakha	Tmax	15.15	16.1	17.4	19.8	22.9	25.4	27.2	28.3	26.9	23.7	20.1	17.2
	Tmin	20.8	20.6	21.7	24.4	27.7	29.8	30.8	31.9	30.8	27.7	24	21.7
	RH%	76.3	72.4	71.4	71.6	67.9	71.4	72.7	73.5	68.7	69.1	71.6	74.6
	WS	4.2	5.7	7.6	6.8	6.8	7.2	8.1	8.1	6.0	4.7	6.1	4.2
	SR	11.4	14.4	19.8	23.7	27.1	29.5	28.9	26.6	22.8	17.6	13.2	10.6
	ET_0	3.1	3.6	3.1	5.7	6.6	7.7	8.0	7.7	6.5	4.9	3.8	3.3
Gemmeiza	Tmax	19.5	20.6	23.2	27.7	32.0	34.0	34.5	34.6	32.7	30.5	25.6	21.7
	Tmin	5.2	5.6	7.3	10.0	14.1	17.2	19.2	19.1	17.1	15.0	13.1	8.5
	RH%	86	85	82	76	70	70	75	78	80	80	81	85
	WS	0.8	1.2	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.7	0.8
	SR	12.4	15.6	21.0	24.8	27.3	29.3	28.7	26.7	22.9	18.7	13.9	11.9
	ET_0	3.3	4.2	5.7	7.6	8.9	9.8	9.3	8.8	7.6	6.0	4.2	3.4
Giza	Tmax	23.0	22.9	25.5	30.3	35.5	36.0	36.5	38.0	36.5	30.9	26.1	30.4
	Tmin	11.1	10.3	12.6	15.2	19.3	22.1	23.3	24.8	22.5	18.5	13.9	17.1
	RH%	67	66	60	57	46	53	59	59	58	64	59	58.1
	WS	1.1	1.5	2.2	2.3	2.0	2.0	1.9	1.7	1.3	1..2	1.4	1.8
	SR	12.3	15.1	20.0	23.6	26.3	28.4	27.9	25.7	22.3	17.7	13.4	11.5
	ET_0	3.4	4.2	5.5	7.3	8.7	9.5	9.4	8.8	7.5	5.8	4.2	3.5
Fayoum	Tmax	20.3	22.0	25.1	30.1	34.0	35.8	36.7	36.5	33.7	31.2	26.5	21.8
	Tmin	6.1	7.3	9.9	12.9	17.2	19.7	21.2	21.5	19.6	17.1	13.1	8.5
	RH%	66	60	53	47	42	43	50	51	58	59	62	70
	WS	1.2	1.7	2.1	2.4	2.8	3.0	2.6	2.4	2.6	2.8	1.5	1.0
	SR	13.1	16.4	21.6	24.9	27.8	29.8	28.9	27.1	23.4	18.5	14.2	12.3
	ET_0	3.6	4.7	6.1	8.2	9.6	10.4	10.1	9.7	8.3	6.4	4.5	3.7
Shandweel	Tmax	22.5	24.5	28.1	33.2	36.5	37.5	37.5	37.5	34.1	31.7	28.7	24.0
	Tmin	4.6	6.0	8.8	13.5	17.8	20.0	20.5	21.0	20.3	18.0	12.2	7.7
	RH%	80	80	61	47	40	46	53	54	59	67	72	76
	WS	1.3	1.6	1.9	1.9	2.2	2.2	1.9	1.9	2.3	1.9	1.6	1.4
	SR	15.0	18.8	23.3	25.8	27.3	29.2	28.3	27.1	24.4	20.5	16.5	14.3
	ET_0	4.3	5.5	7.3	9.6	10.9	11.7	11.4	11.1	9.9	7.9	5.5	4.3

*Tmax and Tmin = maximum and minimum temperatures C^o, RH% = Air relative humidity%, WS= Wind speed ($msec^{-1}$), SR= solar radiation ($MJday^{-1}m^{-2}$) and ET_0= Reference evapotranspiration ($mmday^{-1}$).

The experiments were carried out during the distinguished growing seasons in Egypt as follows:

A- Summer season, extending from March to June

B- Nili season, extending from July to October

C- Winter season, extending from November to March.

The adopted irrigation intervals were as follows: -

a- Irrigating at 8, 12 and 16 days' intervals designated as short, medium and long irrigation intervals, respectively, were assessed in the summer season.

b- Irrigating at 10, 15 and 20 days' intervals were assessed in the Nili and winter seasons.

Under each location, a field experiment was executed in 2014 including the adopted irrigation intervals which assessed in Randomized Complete Blocks Design, and replicated four times. The recommended agricultural practices for each location concerning sunflower production i.e. seed bed preparation, fertilization, weed and insects control etc. were done. The experimental plot area was not less than 42 m^2. Furrow irrigation was adopted for conveying irrigation water to the grown plants at all of the experimental sites.

Water consumptive use:

Soil moisture percentage was determined (on weight basis) just before and 48 hrs after each irrigation as well as at harvest to compute the actual consumed water as stated by Hansen *et al.* (1979) as follows:

$$CU = SMD = \sum_{i=1}^{i=4} \frac{\phi 2 - \phi 1}{100} \times Dbi \times Di$$

Where:

CU =Water consumptive use (mm) in the effective root zone of 60 cm soil depth.

SMD =Soil Moisture Depletion, mm.

i = Number of soil layer (1- 4).

D_i =Soil layer thickness (150 mm).

D_{bi}= Bulk density (Mgm^{-3}) of the soil layer.

ϕ_1=Soil moisture percentage (wt/wt) before irrigation and

ϕ_2=Soil moisture percentage (wt/wt), 48 hours after irrigation.

At harvest, heads of a guarded plant area (not less than $10m^2$) were threated and the seed yield was determined and expressed as $kgfad^{-1}$. Homogeneity test for seed yield at different locations indicated a significant difference. So, data of seed yield for each location were subjected to the statistical analyses (RCBD) according to Steel and Torrie (1980) and the means were compared at the level of 0.05 significance.

Water productivity

Water productivity with dimensions of kg m^{-3} is defined as the ratio of the mass of marketable yield (Ya) to the volume of water consumed by the crop (ETa) as follows:

Water Productivity (Kgm^{-3}) = Ya/ETa ......Molden 2003

Where:

WP=water productivity (kgm^{-3})

Ya=sunflower seed yield ($kgfed^{-1}$).

ETa=crop water use or crop evapotraspiration (m^3fed^{-1}).

RESULTS AND DISCUSSION

A – Sunflower crop productivity

A1-Impacts location

Data in Table 3 indicated that, regardless the assessed growing season and irrigation interval, sunflower yield was significantly altered due to the selected locations. The highest sunflower seed yield was produced under Middle Delta (Gemmeiza) conditions which was slightly higher than that under Middle Egypt (Giza). The percentage of the excess in Middle Delta (Gemmeiza) conditions reached 12.40, 46.45 and 12.03 %, comparing to seed yields produced under North Nile Delta (Sakha), Middle Egypt (Fayoum) and Upper Egypt (Shandweel) conditions, respectively. Reduction in seed productivity under Fayoum conditions may be attributed to soil compaction which is important for soil aeration and water storage. In this sense, Graecen and Giandron (1982) demonstrated that soil profile characteristics are important for root distribution and affect plant water uptake and growth. The present variations in seed yield due the different locations are mainly attributed to the prevailing weather, soil and environment conditions. The present results were previously confirmed under the different Egyptian circumstances e.g. Abdel-Wahab et al. (2005) on sandy soil at Ismaillia , reported that the sunflower yield potential ranged from 1.056 to 1.147 $tonfad^{-1}$ and from 0.477 to 0.537 $tonfad^{-1}$, respectively under furrow and drip irrigation. In addition, under clay loam soil, Abdel-Mawgoud et al. (2009) reported that sunflower yield potential ranged 1.87 – 2.05 $tonfad^{-1}$ in Upper Egypt (Assiut Governorate), regardless irrigation system. Abdou *et al.* (2011) and Ashry *et al.* (2013) at Fayoum district found that sunflower seed yield potential amounted to 884.94 and 881.74 $kgfad^{-1}$, respectively. EL-Sharaihy (2014) reported that yield potential for sunflower (var. Sakha 53) were (1714.3 - 1810.0 $kgfad^{-1}$), (1714.3 – 1723.3 $kgfad^{-1}$) and (1261.3 – 1700.3 $kgfad^{-1}$) at Gemmeiza, Sakha and Nubaria zones, respectively. Worldwide, Agele (2003) reported that the weather factors of a season influenced phenology, growth, biomass production and seed yield in sunflower. The crop interacted with the soil and aerial environment causing variations in biomass accumulation and grain yield. The author added that regression of some growth parameters of sunflower and specific weather variables were highly significant. Moreover, Montemurro et al. (2007) stated that the weather conditions strongly influenced yield and N uptake for sunflower. In connection, Ali and Noorka (2013) in Pakistan, reported that full irrigation of sunflower crop e.g. irrigation at seedling establishment, vegetative phase, button stage and at achenes formation resulted in the highest achene yield amounted to 2415.68 $kgha^{-1}$, whereas irrigation at plant establishment exhibited the lowest achene yield as 1275.35 $kgha^{-1}$.

A2- Impacts of growing seasons

Data in Table 3 revealed that regardless the location and irrigation interval, growing season has significant effect on sunflower seed yield and summer season exhibited the highest figure (1050.94 $kgfad^{-1}$). The increase in seed yield with summer season was higher by 49.68 and 120.6, comparing to Nili and winter seasons, respectively. Such findings are attributable to prevailing weather conditions during the growing season where each growing season is unique, with its own weather. In this sense, Agele (2003) stated that variations in the prevailing soil and climatic environments of the different seasons of sowing are characterized by differences in evaporative demand, temperatures, radiation and precipitation which directly affected sunflower performance. Allam *et al.* (2003) found that the planting date exerted a highly significant influence on sunflower seed yield. For temperate climates the optimum planting date for early as well as late maturing varieties is between late spring and early summer. Perniola et al. (2006) in Italy reported that sunflower grain yield was significantly influenced due to March and April sowing dates. In addition, delay in planting results in shortening of the vegetative period and early maturity, causing a decrease in head diameter and seed weight, (FAO, 2013).

A3- Impacts of irrigation intervals

Regardless location and growing season, the assessed irrigation intervals significantly influenced seed yield productivity, Table 3. Medium irrigation interval (12- 15 days interval) surpassed both short (8- 10 days interval) and wide irrigation (16- 20 days interval) with increases reached to 14.84 and 20.87 %, respectively. EL-Sharaihy *et al.* (2013) at Gemmeiza, found that the highest sunflower seed yield (810.47 $kgfad^{-1}$) resulted from irrigating at 14 days interval as compared with 21 and 28 days ones. In connection, long periods of severe soil water deficit at any growth period cause leaf-drying with subsequent reduction in seed yield, FAO, 2013. Moreover, El Naim and Ahmed (2010) In Sudan, found that irrigation interval of 7 days (high irrigation regime) significantly improved sunflower seed yield, comparing to medium and lower irrigation regimes e.g. 14 and 21 days intervals, respectively. Furthermore, Yagoub *et al.* (2010) stated that irrigation interval every 7 and 14 days gave better sunflower growth and yields comparing to 21 and 30 days intervals. Hussain and Qureshi (2000) In Pakistan reported that the maximum sunflower seed yield of 3119 $kgha^{-1}$ was obtained with six irrigations against 2200 $kgha^{-1}$ with two irrigations. In parallel, El-Naggar (1991) grew sunflower CV. Mayak that was irrigated at 7, 14 or 21 day intervals or not irrigated (rainfed) and reported that plant growth and seed yield were improved by all irrigation treatments and were the best with irrigation every 14 days. Taherabadi *et al.* (2013) found that the highest sunflower seed yield, 4219 $kgha^{-1}$, resulted from irrigating at 10 days interval, whereas with 15 and 20 days intervals the seed yield values were reduced to be 3507 and 2819 $kgha^{-1}$, respectively.

Table 3: Sunflower seed productivity, $kgfad^{-1}$, as influenced by locations, growing seasons, irrigation intervals and interaction in 2014.

Locations	Growing season	Irrigation intervals*			Average
		Short	Medium	Long	
Sakha	Summer	1165	1275	950	1130.0
	Nili	590	700	500	596.67
	Winter	520	623	347	496.67
Average		758.33	866.00	599.00	741.11
L.S.D at 0.05	A (Growing season)	15.521			
	B (Irrigation) intervals)	15.521			
	A×B	46.565			
Gemmeiza	Summer	1121	1349	1051	1173.67
	Nili	807	895	704	802.00
	Winter	513	618	439	523.33
Average		813.67	954.00	731.33	833.00
L.S.D at 0.05	A (Growing season)	9.503			
	B (Irrigation) intervals)	9.503			
	A×B	28.511			
Giza	Summer	1152	1406	1101	1219.67
	Nili	750	760	696	735.33
	Winter	550	556	493	533.00
Average		817.33	907.33	763.33	829.33
L.S.D at 0.05	A (Growing season)	6.495			
	B (Irrigation) intervals)	6.495			
	A×B	19.486			
Fayoum	Summer	796	741	634	723.67
	Nili	724	660	575	653.00
	Winter	431	292	266	329.67
Average		650.33	564.33	491.67	568.78
L.S.D at 0.05	A (Growing season)	6.985			
	B (Irrigation) intervals)	6.985			
	A×B	20.956			
Shandweel	Summer	1193	1039	791	1007.67
	Nili	809	743	619	723.67
	Winter	545	500	453	499.33
Average		849.00	760.67	621.00	743.56
L.S.D at 0.05	A (Growing season)	9.393			
	B (Irrigation) intervals)	9.393			
	A×B	28.181			
Average for all growing season	Summer	1085	1162	905	1051
	Nili	736	752	619	702
	Winter	518	518	400	476
Average for all irrigation intervals		778	810	641	743

Note: Irrigation intervals: Irrigating at 8, 12 and 16 days' intervals designated as short, medium and long irrigation intervals in the summer season. Irrigating at 10, 15 and 20 days' intervals were assessed in the Nili and winter seasons.*

A4- Interactions effect on sunflower seed yield

The available bilateral interaction of the adopted locations, growing seasons and irrigation intervals are illustrated in figures1-3. It clear that the highest sunflower seed yield was attained due to the bilateral interactions of Giza location and the summer growing season, Gemmeiza location and the medium irrigation interval and summer growing season and the medium irrigation interval. In addition, the trilateral interaction of Giza location, summer growing season and medium irrigation interval resulted in the highest sunflower seed yield, Table 3.

B – Sunflower water use

B1-Impacts of locations

Data in Table 4 illustrated that the highest water use for sunflower crop was recorded under Upper Egypt (Shandweel) and reached to 484.4 mm. Such higher water requirements, in Upper Egypt, are attributed to prevailing weather conditions encouraging higher crop water demands. Values of water use were 16.05, 12.70, 7.18 and 14.31% under North Nile Delta(Sakha), Middle Nile Delta (Gemmeiza), Middle Egypt (Giza) and Fayoum conditions, respectively, lower than that with Upper Egypt one. The cited literatures revealed varied ET for sunflower grown at different locations in Egypt e.g. Abdel-Mawgoud *et al.*(2009) in Upper Egypt (Assiut Governorate) under clay loam soil conditions, found that sunflower ETa values ranged 474.2 – 479.2 mm as irrigation was practiced at 13% SMD regime, regardless the irrigation system. Furthermore, Abdou *et al.* (2011) and Ashry *et al.* (2013) at Fayoum district reported that irrigating at 1.2 Cumulative Pan Evaporation norms (C.P.E) exhibited the sunflower seed yield potentiality with ET values comprised 49.64 and 51.21 cm comparing to irrigation at 0.6 or 0.8 C.P.E. In connection, water requirements of sunflower vary from 600 to 1000 mm, depending on climate and length of total growing period, FAO 2013. Moreover, Unger (1990) and Stone et al. (1996) stated that the wide range of sunflower ET (200 to more than 900 mm) could be attributed to irrigation level practiced, climatic regions involved and length of growing season. In addition, Yawson et al. (2011) determined water requirement of sunflower, as the optimum level of water required to reach maximum head diameter, to be 672.4 mm $season^{-1}$. The authors added that, based on Blaney-Criddle method, water requirement of sunflower was amounted to 361.2 mm $season^{-1}$.

B2- Impacts of growing seasons

Data in Table 4 illustrated that the highest sunflower ET value, 509.3 mm, was recorded with summer season which tended to reduction with Nili and winter growing seasons to reach 12.88 and 30.45%, respectively, lower than that with summer growing season. Higher ET value with summer growing season could be due to prevailing higher evaporative demands, in particular, temperatures and solar radiation. Variations in the prevailing soil and climatic environments of the different seasons of sowing are characterized by differences in evaporative demand, temperatures, radiation and precipitation which indubitably affect the crop performance, (FAO 2013). In addition, Agele (2003) stated that widely spaced sowing dates provide differences in soil water, temperature and radiation regimes and such factors are further compounded by differences in vapour pressure deficits in the different seasons of planting. Furthermore, Perniola et al. (2006) irrigated sunflower crop at 100% of maximum crop evapotranspiration and found that total water use amounted to 6564 and 7334 $m^3 ha^{-1}$ for the crop sown in March and April 1995 and the corresponding values in 1996 were 8359 and 8391 m^3ha^{-1}, respectively.

Fig.1: Locations and irrigation intervals interaction effect on sunflower seed yield, $Kgfed^{-1}$

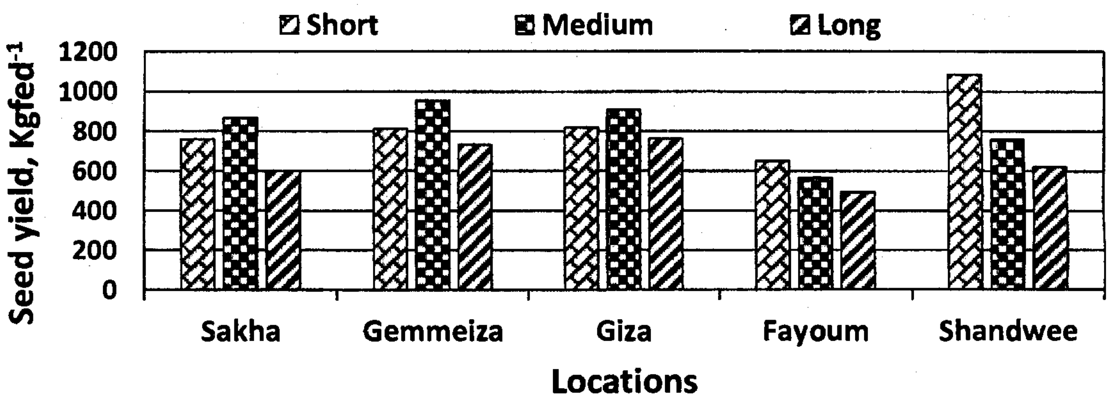


Fig. 2: Locations and growing seasons interaction effect on sunflower seed yield $kgfed^{-1}$

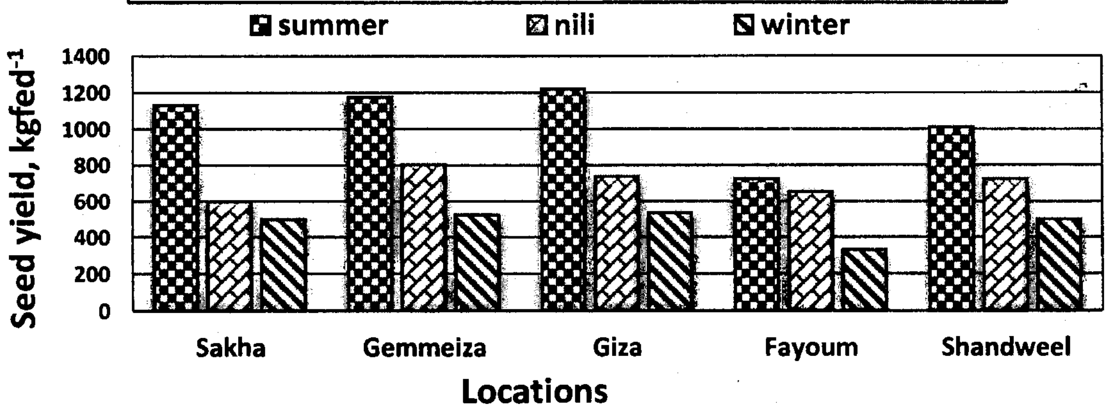


Fig.3: Growing seasons and irrigation inervals interaction effect on sunflower seed yield, $Kgfed^{-1}$

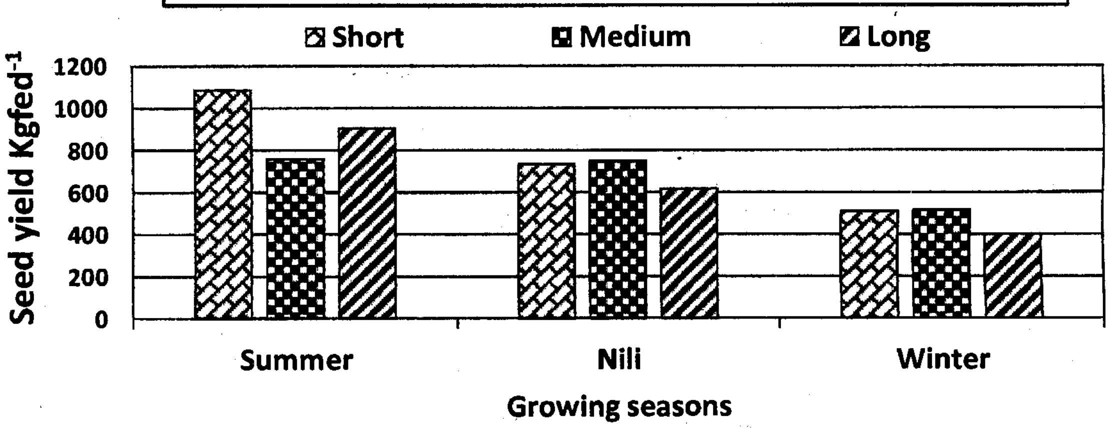


Table 4: Water use for sunflower, mm, as influenced by locations, growing seasons, irrigation intervals and interaction in 2014.

Location	Growing season	Irrigation intervals			Average
		Short	Medium	Long	
Sakha	Summer	547.6	523.8	441.7	504.4
	Nili	451.7	397.6	383.1	410.8
	Winter	342.1	301.9	270	304.6
Average		447.1	407.8	364.9	406.6
Gemmeiza	Summer	539.8	482.6	414.8	479.1
	Nili	442.6	416.2	380.7	413.2
	Winter	416.2	363.4	350.5	376.7
Average		466.2	420.7	382	422.9
Giza	Summer	577.1	541.7	454	524.3
	Nili	521.9	463.6	406.9	464.1
	Winter	386.9	377.1	317.1	360.4
Average		495.3	460.8	392.7	449.6
Fayoum	Summer	486.4	454.5	416.9	452.6
	Nili	500	455.2	395	450.1
	Winter	373.6	341.9	312.6	342.7
Average		453.3	417.2	374.8	415.1
Shandweel	Summer	619	579.5	559.5	586
	Nili	547.6	461.2	432.4	480.4
	Winter	424.5	393.1	342.4	386.7
Average		530.4	477.9	444.8	484.4
Average for all growing season	Summer	553.98	516.42	457.38	509.28
	Nili	492.76	438.76	399.62	443.72
	Winter	388.66	355.48	318.52	354.22
Average for all irrigation intervals		478.47	436.89	391.84	435.74

B3- Impacts of irrigation intervals

Data in Table 4 revealed that, regardless location and growing season, the highest ETc value, 478.5 mm, was recorded due to irrigating at the short interval, which is attributable to frequent irrigation with such irrigation regime. Extending the irrigation interval resulted in lower ETc values reaching to 8.69 and 18.12%, respectively, with medium and wide irrigation intervals lesser than that with short interval. In this sense, Abdou *et al.* (2011) Ashry *et al.* (2013) at Fayoum district reported that irrigating post higher soil moisture depletion i.e. according to 0.6 or 0.8 Cumulative Pan Evaporation (CPE) resulted in reduced ET values, comparing to less soil moisture depletion e.g. 1.2 CPE. In connection, Demir *et al.* (2006) stated that long periods of severe soil water deficit, particularly at water-sensitive sunflower growth stages caused significant limiting evapotranspiration (ET) through stomata closure, reduced assimilation of carbon and decreased biomass production. Moreover, Karam et al. (2007) found that withholding irrigation at early flowering, mid flowering or early seed formation stages resulted in lower sunflower ET values (2- seasons mean) amounted to 22.28, 15.91 and 8.86%, respectively, comparing to full irrigation.

C – Sunflower crop water productivity (WP)

C1-Impacts of locations

Data in Table 5 cleared out that water productivity for sunflower was not greatly affected under North Nile Delta (Sakha), Middle Nile Delta (Gemmeiza) and Middle Egypt (Giza) conditions which ranged from 0.422 to 0.459 kgm^{-3}. Value of water productivity seemed to be reduced under Fayoum and Upper Egypt conditions and reached to 0.317 and 0.359 kgm^{-3}, respectively. Such reduced WP values could be attributable to prevailing climatic conditions which increase the crop water demands more than dry matter production. The available cited literatures, concerning WP for sunflower grown at different locations in Egypt, exhibited different figures, where Abdel-Wahab et al. (2005) found that under Ismailia conditions WUE of sunflower increased and ranged from 0.169 to 0.239 kg seeds/m^3 under high irrigation regime and tended to reduce to (0.168 – 0.234 kg seeds/m^3) and (0.151 - 0.233 kg seeds/m^3), respectively, with medium and low irrigation regimes. Abdel-Mawgoud *et al.* (2009) reported that under climatic conditions of Assiut Governorate irrigating at 13% SMD regime resulted in the sunflower yield potential with WP value ranged from 0.62 to 0.66 kgm^{-3} on consumed water basis under flood irrigation. Abdou *et al.* (2011) and Ashry *et al.* (2013) at Fayoum conditions found that the highest irrigation level i.e. irrigating at 1.2 cumulative pan evaporation (C.P.E.) gave the highest WUE e.g. 0.408 and 0.420 kg seedsm^{-3} of consumed water, respectively, comparing to irrigation at 0.6 or 0.8 CPE regimes. Under irrigation, water utilization efficiency for harvested yield (Ey) for seeds containing 6 to 10% moisture is 0.3 to 0.5 kgm^{-3}(FAO, 2013). Worldwide, Demir *et al.* (2006) reported that the highest water use efficiency (WUE, 7.80 kg ha^{-1} mm^{-1}) was obtained from deficit irrigations at flowering stage. On the contrary, Langeroodi *et al.* (2014) found that severe deficit irrigation i.e. 75 and 90% of maximum allowable depletion of available soil water significantly decreased water-use efficiency for sunflower crop, comparing to 45 and 60% ones.

C2- Impacts of growing seasons

Data concerning WP for sunflower as influenced by the adopted growing season illustrated that the highest WP value, 0.50 kgm^{-3}, was recorded with summer growing season, Table 5. Furthermore, lower WP values amounted to 0.38 and 0.32 kgm^{-3}, respectively, with Nili and winter growing seasons indicating that the prevailing weather conditions during the summer season were encouraging proper crop performance. Variations in the prevailing climatic environments of the different seasons of sowing are characterized by differences in evaporative demand, temperatures, radiation and precipitation which directly influenced sunflower performance. Perniola *et al.* (2006) found that WUE for sunflower were significantly differed due to March or April sowing dates and higher WUE value was noticed under the highest rate of water use regardless sowing date.

Table 5: Water productivity for sunflower, kgm-3, as influenced by locations, growing Seasons, irrigation intervals and interaction in 2014.

Location	Growing season	Irrigation intervals*			Average
		Short	Medium	Long	
Sakha	Summer	0.51	0.58	0.51	0.533
	Nili	0.31	0.42	0.31	0.347
	Winter	0.36	0.49	0.31	0.387
Average		0.393	0.497	0.377	0.422
Gemmeiza	Summer	0.49	0.67	0.6	0.587
	Nili	0.43	0.51	0.44	0.46
	Winter	0.29	0.4	0.3	0.33
Average		0.403	0.527	0.447	0.459
Giza	Summer	0.48	0.62	0.58	0.56
	Nili	0.34	0.39	0.41	0.38
	Winter	0.34	0.35	0.37	0.353
Average		0.387	0.453	0.453	0.431
Fayoum	Summer	0.39	0.39	0.36	0.38
	Nili	0.34	0.35	0.35	0.347
	Winter	0.27	0.2	0.2	0.223
Average		0.333	0.313	0.303	0.317
Shandweel	Summer	0.46	0.43	0.34	0.41
	Nili	0.35	0.38	0.34	0.357
	Winter	0.31	0.3	0.32	0.31
Average		0.373	0.37	0.333	0.359
Average for all growing season	Summer	0.47	0.54	0.48	0.49
	Nili	0.35	0.41	0.37	0.38
	Winter	0.31	0.35	0.30	0.32
Average for all irrigation intervals		0.38	0.43	0.38	0.40

C3- Impacts of irrigation intervals

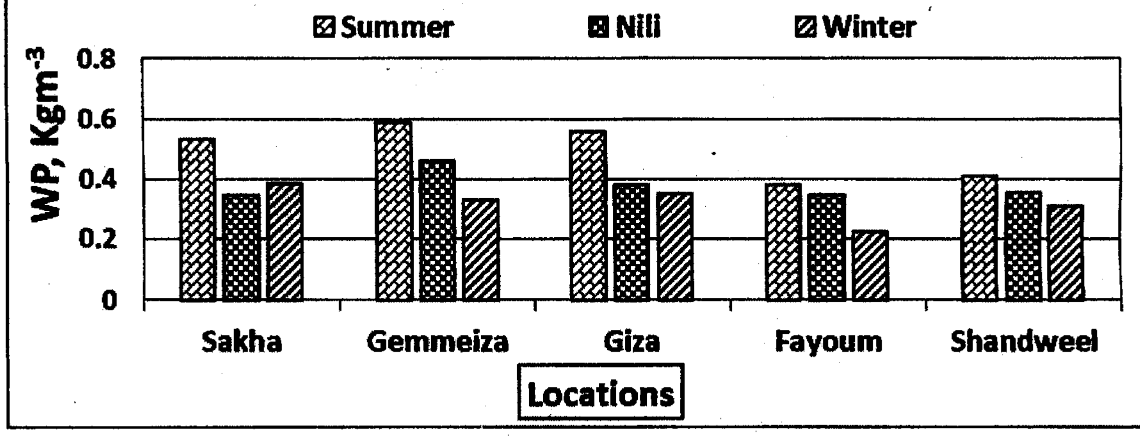
Regardless location and growing season, irrigating sunflower crop at medium irrigation interval exhibited higher WP value which comprised 0.43 kgseedsm^{-3}. With short and wide irrigation intervals WP values tended to be reduced to 11.63 and 11.63%, respectively, lower than the value recorded with medium irrigation interval. Albaji *et al.* (2011) found a different trend where limited irrigation e.g. regulated deficit irrigation (RDI_{50} and RDI_{70}) and partial root zone drying PRD_{50} resulted in the highest (WP (Ir) Y) values, comparing to the conventional irrigation (CI). The authors added that the maximum WUE(Y) was related to RDI50, PRD50 and RDI70 treatments, whereas the minimum one was still associated with CI treatment. In parallel, Rinaldi and Maiorana (2000) found that 33% ETo irrigation regime with an irrigation seasonal amount of 150 mm, showed the highest water use efficiency for sunflower, comparing to100 % ETo regime. Such different trends are attributed to different prevailing soil and weather conditions aside the adopted irrigation treatments. In this sense, Vazifedoust *et al.* (2008) stated that improved irrigation practices in terms of irrigation timing and amount, increased WP as (kg m^{-3}) by a factor of 1.3 for sunflower.

C4-Available bilateral interactions effect on WP for sunflower, kgm^{-3}

The available bilateral interaction of the adopted locations, growing seasons and irrigation intervals are illustrated in figures 4 - 6. It clear that the highest WP values for sunflower were attained due to the bilateral interactions of Gemmeiza location and the summer growing season, Gemmeiza location and the medium irrigation interval and summer growing season and the medium irrigation interval. Furthermore, the trilateral interaction of Giza location, summer growing season and medium irrigation interval resulted in the highest WP value for sunflower e.g. 0.62 kgm^{-3}, Table 5.

On conclusion and based on the obtained results, it is better to grow sunflower under Gemmeiza, Sakha and Giza conditions in summer season and practiced irrigation at the medium irrigation interval in order to gain reasonable WP values with acceptable seed yields. With respect to Fayoum and Shandweel locations, growing sunflower may require different soil and/or water management which are capable to induce better crop performance.

Fig.4: Locations and growing seasons interaction effect on WP, for sunflower Kgm^{-3}



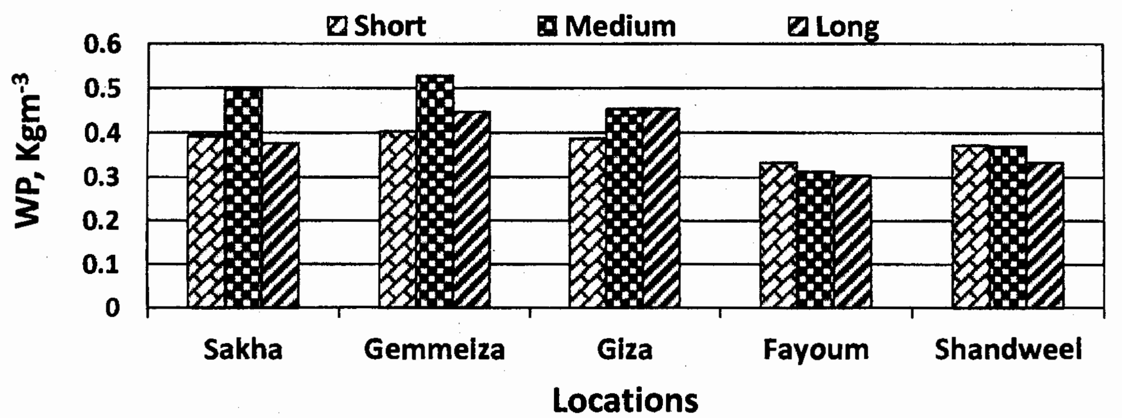


Fig.5: Locations and irrigation intervals interaction on WP, for sunflower Kgm^{-3}

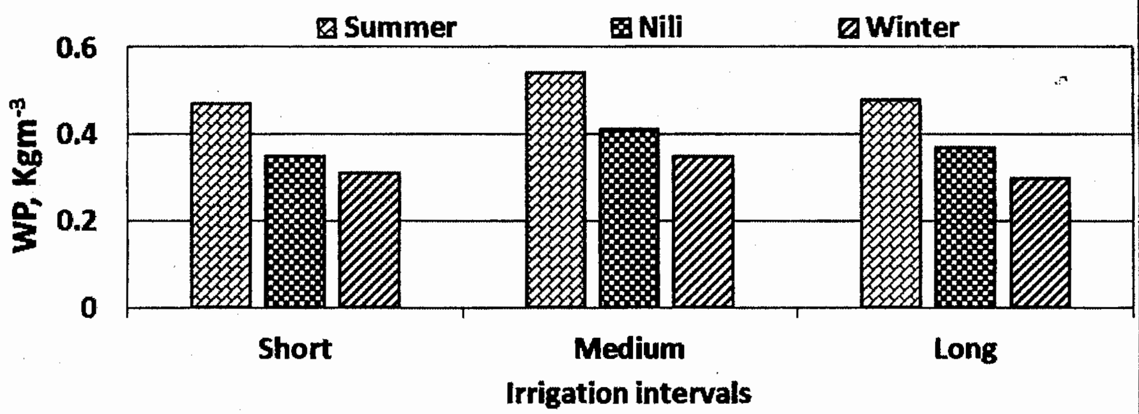


Fig.6: Growing seasons and irrigation intervals interaction effect on WP for sunflower, Kgm^{-3}

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تقييم انتاجية مياه الري في عباد الشمس تحت ظروف مناطق مختلفة فى مصر

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الملخص العربي

أقيم هذا البحث خلال عام ٢٠١٤ بمناطق مختلفة في مصر هي سخا (شمال دلتا النيل) – الجميزة (وسط دلتا النيل) – الجيزة والفيوم (مصر الوسطي) – شندويل (مصر العليا) و ذلك لدراسة تأثير موسم الزراعة (الصيفي – النيلي – الشتوي) ومناوبة الري (قصيرة – متوسطة – طويلة) علي انتاجية عباد الشمس وانتاجية مياه الري تحت ظروف الري السطحي بالخطوط. يهدف البحث الي معرفة أفضل الظروف للحصول علي أعلي انتاجية للبذور وكذا أفضل انتاجية لمياه الري لتقليل الفجوة الواسعة بين انتاجية – استهلاك زيوت الطعام في مصر. هذا ويمكن تلخيص أهم النتائج فيما يلي:–

- انتاجية البذور اختلفت تبعا للمناطق المناخية وسجلت أعلي القيم (٨٣٣,٠ و ٨٢٩,٣٣ كجم فدان$^{-1}$) في الجميزة والجيزة علي الترتيب. اختلفت قيم الاستهلاك المائي لعباد الشمس و سجلت أعلي قيمة (٤٨٤,٤ مم) في شندويل – مصر العليا ، ويعزي ذلك الي الظروف الجوية السائدة والتي تؤدي الي قيم عالية للاحتياجات المائية للمحصول. بينما لم تختلف قيم الاستهلاك المائي كثيرا تحت الظروف المناخية السائدة في كل من الجميزة – سخا – الجيزة. لوحظت قيم عالية ومتقاربة لانتاجية مياه الري في الجميزة والجيزة وسخا حيث كانت القيم ٠,٤٦ و ٠,٤٣ و ٠,٤٢ كجم م$^{-3}$ علي التوالي .
- محصول البذور كان الأعلي في العروة الصيفي (١٠٥٠,٩٤ كجم فدان$^{-1}$) وتفوق ب ٤٩,٦٨ و ١٢٠,٦% عن العروتين النيلي والشتوي, علي الترتيب. مع العروة الصيفي سجلت أعلي القيم للاستهلاك المائي لعباد الشمس (٥٠٩,٣ مم) والذي انخفض ب ١٢,٨٧ و ٣٠,٤٤% في العروتين النيلي و الشتوية, علي التوالي. انتاجية مياه الري كانت الأعلي في العروة الصيفية (٠,٤٩ كجم م$^{-3}$) وانخفضت لتصل الي ٠,٣٠ و ٠,٣٢ كجم م$^{-3}$ في العروة النيلية و الشتوية, علي التوالي.
- أظهرت مناوبة الري المتوسطة أفضل محصول بذرة بزيادة قدرها ١٤,٨٤ و ٢٦,٣٩% عن كلا من المناوبتين القصيرة والطويلة, علي التوالي. أعلي استهلاك مائي لعباد الشمس (٤٧٨,٥ مم) كان باجراء الري تبعا للمناوبة القصيرة والذي انخفض بمقدار ٨,٦٩ و ١٨,١٢% تحت ظروف كلا من المناوبتين المتوسطة والطويلة, علي التوالي. الري تبعا للمناوبة المتوسطة أظهر قيمة عالية لانتاجية مياه الري (٠,٤٣ كجم م$^{-3}$) والتي انخفضت ب ١١,٦٣ و ١١,٦٣%, علي التوالي, مع كلا من المناوبتين القصيرة والطويلة.

بناءا علي النتائج السابقة, يفضل انتاج عباد الشمس تحت ظروف كل من الجميزة , الجيزة و سخا في الموسم الصيفي مع الري طبقا للمناوبة المتوسطة للحصول علي قيم مقبولة للمحصول و انتاجية مياة الري. بالنسبة الي منطقتي الفيوم و شندويل ربما يحتاجان الي ادارة مختلفة للمياه و/أو التربة للحصول علي قيم مقبولة لمحصول عباد الشمس و انتاجية مياه الري.

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