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IMPACT OF PLANTING DISTANCES AND IRRIGATION REGIMES ON SUNFLOWER (*Helianthus annus* L.) PRODUCTIVITY AND WATER USE EFFICIENCY

Fares S.M. Gomaa* **and A. A. H. El-Khawaga**

Agron. Dept., Fac. Agric., Zagazig Univ., Egypt.

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ABSTRACT

In order to study the effect of two planting distances and four irrigation regimes on growth traits, seed yield and water use efficiency of sunflower (*Helianthus annus* L.) plants, two filed experiments were conducted during 2020 and 2021 summer seasons in a loamy sand soil at Abu Hammad District, Sharqia Governorate, Egypt. Split plot design in a randomized complete block design in three replicates was used. The two planting distances between hills (20 and 30 cm) were assigned to the main plots, sub-plots were devoted to four irrigation regimes (Irrigation at 50% available water "AW"; 75%, 50% and 25% of the 50% AW). Results stated that irigating at 50% and 75% of AW were at par of in each of leaf area index, plant height, stem diameter, seed yield, head diameter, and number of seeds/head, in both seasons. Hence, saving about 21.97% (358.88 m^3/faddan) of the full water needed for irrigation. Planting density based on planting distances where increasing plant density from 20000 to 30000 plant/faddan (4200 m^2) through narrowing planting distances form 30 cm to 20 cm improved each of plant height, leaf area index, and seed yield as well as raising water use efficiency.

INTRODUCTION

Sunflower (*Helianthus annus* L.) is one of the most important oil crops, which is sown in large acreage globally, moreover, it is considered one of the drought-tolerant and water efficient crops **(Bartholomew and Olubukola, 2020)**. Therefore, sunflower is suitable crop for cultivation in new cultivated sandy soils, whereas leakage of water and scarcity of rainfall are concerted as in arid regions. Planting density affects crop productivity through the efficiency of its effective exposure to the effective solar radiation during the process of photosynthesis; in addition, the optimum density lessen competition among plants for growth requirements. Accordingly, determining number of plants per unit area is an exigent practice.

Light intensity and the temperature available to plants during growing season are two of the most important varying factors that are affected by planting density wherein they affect mostly the plant physiological processes. **Zervoudakis *et al.* (2012)** mentioned that good lighting comes from the availability of the appropriate space among plants, which exhibits receiving the largest amount of light, and thus stimulate plants to perform effective photosynthesis.

Ahmed and Ahmed (2010) found that there was a significant effect of increasing the distance between plants from 15 cm to 20 cm on each of head diameter and number of seeds/head. These results are consistent with the findings of several researchers such as **Reddy *et al.* (2003)**, **Taghdiri *et al.* (2006)**. **Süzer (2010)** found

* **Corresponding author: E-mail address:** fares_soliman2010@yahoo.com
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that increasing plant density decreased head diameter, where decrement of head diameter in closely spaced plants may be ascribed to the competition among plants for moisture, light and carbon dioxide.

Wajeeha *et al.* (2019) recorded a significant increase in number of seeds/ head, 100-seed weight and head diameter by decreasing plant density (wide distances). As well, **Stephen and Orvin (1982)** indicated that increasing distance between hills from 16 to 20 cm caused an increase in head diameter, number of seeds/head and seed weight/ plant.

Scarcity of water makes the optimum irrigation time is essential to maintain the crop productivity. Therefore, irrigating at the appropriate quantities and times and distributing it homogeneously in the field guarantee the optimum and effective water use for more crop productivity and less water consumption. The importance of studying water consumption in general is due to its direct relationship to scheduling irrigation times and number and selection the suitable crops for sowing in any region. **Buriro *et al.* (2015)** clarified that the water consumption of sunflower crop is 480 millimeters and indicated that the amount of water consumed depended on growth stage and the prevailing environmental conditions during the growing season.

Human *et al.* (1990) mentioned that water stress on sunflower during vegetative growth decreased yield by 17%. Water stress hampers stem elongation and leaf area, and consequently depress photosynthesis. **Abdou *et al.* (2011)** avouched that water dose and its distribution affect significantly on seed yield. They added that plant height was significantly affected negatively by water stress where it was decreased from 108 cm to 85 cm when water supply was reduced from 100% field capacity to 30%; that result is in agreement with **Nezami *et al.* (2008)**. **Elijah and Zimba (2018)** postulated that deficit irrigation at 50% of field capacity reduced sunflower yield and its components by 49% in comparison with irrigation at 100% field capacity.

This experimental study aimed to investigate the effect of water stress on sunflower growth and yield as well as its components, in addition to finding the compatibility between the appropriate plant density and the amount of water added to obtain the highest productivity. In addition, water consumption was analyzed all over the growing season and correlated with soil water content.

MATERIALS AND METHODS

Two filed experiments were conducted in an experimental field at Abu Hammad District, Sharqia Governorate, Egypt (30°53'93.0"N 31°70'57.5"E) during 2020 and 2021 summer seasons. The study aimed to investigate the effect of two planting distances and four irrigation regimes on growth, yield and its components of sunflower cultivar, Giza 102.

Statistical Layout

Split plot in a randomized complete block design in three replicates was used to carry out the study. Two planting distances were assigned to the main plots, sub-plots were devoted to four irrigation regimes. Each sub-plot area was 16 m^2(4×4 m), which included 6 ridges, 66 cm apart. A distance of 1.5 m among plots was left to fade the overlapping of treatments.

Agricultural Practices

The experiment was sown on 1^{st} May in both seasons. All agricultural practices were conducted as recommended under the region conditions. Potassium fertilizer as potassium Sulfate (48% K_2O) and phosphorus fertilizer as ordinary superphosphate (15.5% P_2O_5) were applied before planting in a dose of 50 and 100 kg/fad., respectively. Nitrogen fertilizer as ammonium nitrate (33.5% N) was applied at rate of 100 kg/

fad., the amount of nitrogen fertilizer was splitting into 3 equal doses supplied at sowing, 15 and 30 DAS just before irrigation, the preceding crop was faba bean (*Vicia faba* L.) in both seasons. Thinning to a plant/hill took place 14 days after sowing (DAS). Hoeing was done twice at 17 and 32 DAS. Harvest took place at 82 DAS.

Soil Sampling and Analysis

Soil samples were taken from the upper 40 cm soil surface during soil preparation; Soil chemical and physical analyses were carried out according to the methodology of **Jackson (1958)** and **Lindsay and Norvell (1978)**; the results are shown in Table 1.

Planting Distances as Density

Two planting distances between hills (20 and 30 cm) were experimented and it were translated into planting density, where 20 cm distance between plants provided 30000 plant/fad., while 30 cm planting distance provided 20000 plant/fad.

Water Moisture Measurements

Irrigation was through plastic tubes connected to a pump with a water meters to evaluate the initial consumption of each experimental unit.

Soil water retention curve was graphically represented (Fig. 1) through estimating the relationship between the suction tension (matric potential/ suction power) of a soil sample and the volumetric moisture content at different tensions (0.1, 0.33, 5, 10 and 15 bar) according to **Madankumar (1985)**. Field capacity (FC) and permanent wilting point (PWP) are is the bulk water content retained in soil at 0.33 bar and 15 bar, respectively, of hydraulic head or suction pressure (**Rai *et al.*, 2017**).

Volumetric method for measuring soil moisture content was used according to the equation of **Bonnell *et al.* (1991)** as follows:

$$\theta_V = \theta_{W \times BD}$$

Where, θ_V is the soil moisture content based on Volume, θ_W is the soil moisture content based on weight and BD is the soil bulk density (Mg/m^3). Field capacity and wilting point percentage of whole soil samples based on weight were 16.19 % and 8.16 %.

Soil available water was calculated from the difference between the moisture content at field capacity and the permanent wilting point (**FAO, 1985**) and the total available water content as added at each irrigation time was calculated according to the following equation **(Ali, 2010)**

$$W = a.A_s \left(\frac{\%Pw^{Fc} - \%Pw^{Wp}}{100}\right)\frac{D}{100}$$

Where, W is water amount, a is the irrigated area (m^2); A_s is soil row density (1.33 Mg/m^3); P_w^{Fc} is the percentage of soil moisture based on weight at field capacity; P_w^{Wp} is the percentage of soil moisture just before irrigation and D is soil depth (40 cm). Total available water was 179.42 m^3/ fad./time. Hence, irrigation regimes were as shown in Table 2, taking into account that equal amounts of water were added to the experimental unit until the field capacity level at the first irrigation to facilitate the germination process. Then, starting from the second irrigation, the four irrigation treatments declared in Table 2 were applied.

Studied Characters

Plant height (cm) was measured from the soil surface to the base of the head **(Heady, 1957)**, Leaf area index (LAI) was calculated at 60 DAS as follows LAI = leaf area/ ground area, m^2/m^2 according to **Watson (1947)**, Stem diameter (cm) was also mesaured. Ten plants from the intermediate ridges of each experimental unit were randomly taken to calculate the yield and its components such as head diameter (cm), No. of seeds/head, 100 seed weight and seed yield (kg/ fad.).

Table 1. Physical and chemical properties of the experimental location

Property	Value
Physical properties	
Soil particle distribution	
Sand (%)	83.74
Silt (%)	7.11
Clay (%)	9.15
Soil texture*	Loamy sand
Organic matter (g kg^{-1})	5.13
pH**	7.14
EC (dSm^{-1}) ***	0.83
Field capacity (FC)	16.19%
Permanent wilting point (PWP)	8.16 %
Chemical properties	
Soluble cations and anions, (mmolc L^{-1})	
Ca^{2+}	1.58
Mg^{2+}	0.38
K^{+}	0.86
Na^{+}	2.74
$CO_3^{=}$	--
HCO_3^{-}	1.50
Cl^{-}	2.24
$SO_4^{=}$	1.28
Total N (g kg^{-1})	5.18
Total P (g kg^{-1})	0.19
Total K (g kg^{-1})	1.87
Available N, (g kg^{-1}soil)	0.07
Available P, (g kg^{-1}soil)	0.02
Available K, (g kg^{-1}soil)	0.22

Notes: *Soil texture was assigned using International Society of Soil Sciences soil texture triangle

**Soil-water suspension 1: 2.5, ***Soil water extract 1: 5

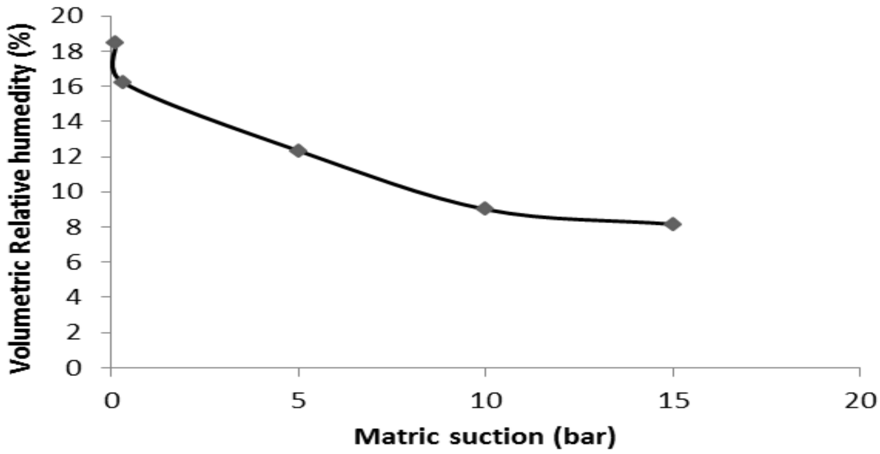

Fig 1. Soil characteristic retention curve

Table 2. Irrigation regimes

Irrigation regime	Irrigation at	No. of irrigation times	1st irrigation (m^3/fad.)	2nd:17th irrigation (m^3/fad.)	Water amount (m^3/fad./ season)	Water amount (m^3/plot in each irrigation)
I_1	50% AW	17	197.42	89.71	1632.78	6.22
I_2	75% of I_1	17	197.42	67.28	1273.90	4.85
I_3	50% of I_1	17	197.42	44.85	915.02	3.48
I_4	25% of I_1	17	197.42	22.42	556.14	2.11

AW= Available water

Water-use efficiency (WUE, kg m^{-3}) was calculated as the ratio of grain yield, seasonal evapotranspiration "ETc" (**Bai *et al.*, 2016)** as following:

WUE = GY/ET

Where, GY is seed yield and ET is the total water Evapotranspiration (mm). Seed yield was determined by harvesting the central two rows in each plot and grain moisture was adjusted to 14.5%. Total water Evapotranspiration was considered as the total irrigation water consumption (m^3) which will be translated into water loses (**Allen *et al.*, 2007**).

Statistical Analysis

An analysis of variance was conducted for the studied traits for each season separately. The least significant difference (LSD) was used to compare the averages. Data recorded from each plot were subjected to the analysis of variance (ANOVA) of the Split plot in a randomized complete block design according to **Donald (1978)** using COSTAT-Statistics Software 6.400 package as described by **Cardinali and Nason (2013).**

RESULTS AND DISCUSSION

Growth Characteristics

Effect of planting distance

Planting distances significantly affected plant height (cm), and leaf area index (LAI) in both seasons, while stem diameter (cm) was significantly affected in the first season only (Table 3). Sunflower plants were taller with larger LAI under dense planting due to closer hill spacing (20 cm) compared with wider hill spacing (30 cm) *i.e.* under lower denseness , that was appreciable in both

Table 3. Plant height (cm), stem diameter (cm) and leaf area index (LAI) as affected by planting distances and irrigation regimes

Main effects and interaction	Plant height (cm)		Stem diameter (cm)		LAI	
Planting distances(D)	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
D_1 (20 cm)	153.72	151.65	1.56	1.67	2.29	2.27
D_2 (30 cm)	143.18	137.08	1.74	1.79	1.69	1.61
F test	*	*	*	NS	*	*
Irrigation regimes (I)						
I_1 (at 50% available water)	168.00 a	161.50 a	1.85 a	1.87 a	2.44 a	2.31 a
I_2 (75% of I_1)	162.80 a	157.10 a	1.76 a	1.92 a	2.50 a	2.40 a
I_3 (50% of I_1)	139.80 b	138.10 b	1.58 b	1.63 b	1.78 b	1.73 b
I_4 (25% of I_1)	123.20 c	120.80 b	1.41 c	1.51 b	1.24 c	1.34 b
F test	*	*	*	*	*	*
D × I	*	*	*	*	*	*

*, ** Significant at 5% and 1% levels of probability, respectively; NS = Not-significant

seasons. Stem diameter in the firsst season was less under dense planting (1.56 cm) compared with wider hill spacing, wherein stem diameter valued 1.74 cm. Wider distance among plants aid in more penetration of sun light, which causes the photo-degradation of Auxin, and depressed cell elongation (**Bajehbaj, 2010**). The wider distance (30 cm) caused an increase in stem diameter, due to the increase in the thickness of stem xylem and the phloem at stem (**Sehgal *et al.*, 2018)**.

Effect of Irrigation regimes

Results presented in Table 3 indicate a significant decrement in plant height (cm) stem diameter (cm), and LAI due to the lack of irrigation water in both seasons. The tallest plants were attained due to the application of the standard irrigation regime (I_1) in first season (168.00 cm) and second one (161.50 cm). Height of sunflower plants was at par without significant different under irrigation regimes I_1 and I_2 Sunflower plant height under decreasing the amount of irrigation water up to 50% (I_3) and/or 25% (I_4) of the standard irrigation water amount (I_1) was harshly affected, so plants were shorter (139.8 and 131.1 cm) in I_3 as well as (123.2 and 120.8 cm) in I_4 in 1st and 2nd seasons, respectively.

The lack of available water for plants when treated with I_4 hampered the rate of cell division and elongation, the uptake and transportation of soluble elements, and consequently decreaseed in plant height **(Soleimanzadeh *et al.*, 2010)**. This result agrees with **Riahinia (2003)** and **Nezami *et al*. (2008)** who concluded that water stress caused a significant decrease in plant height and attributed their results to the decrease of water potential of stem cells below the level required for cell elongation, which resulted in short internodes and consequently, less plant height.

The decrease in stem diameter under irrigation regime I_4 compared to I_1 and I_2, which were significantly similar in significance, could be attributed to the low number of vascular bundles or their size or both due to the lack of water and the inability of plants to absorb nutrients. This agrees with **Rauf (2008)** findings.

The stomata closure due to drought lessen leaf area and inhibit photosynthesis, causing a decrease in absorption and plant growth (**Kafi *et al.*, 2000**). Stem diameter has an important role on final seed yield, which by nutrients absorption increases; thus, expanding the source and giving more opportunity to the seeds that represent the sink for nutrients accumulation **(Sehgal *et al.*, 2018)**.

The value of leaf area index (LAI) decreased with the decrease in quantities of irrigation water, as shown in Table 3. Irrigation treatment I_4 gave the lowest value of LAI, which were 1.24 and 1.34 in 1^{st} and 2^{nd} seasons, respectively, and then the value of leaf area index increased until it reached its highest value of 2.50 and 2.40 for I_2 irrigation and did not differ significantly from I_1 irrigation in both seasons. This result agrees with what **Karam *et al.* (2007)** stated that the decrease in the water potential of the leaves and their relative water content reduced their ability to elongate and swell, which caused a reduction in the leaf area, so decreased the leaf area index.

Seed Yield and its Components

Effect of planting distance

Results given in Table 4 testify the impact of planting distances on head diameter (cm), No. of seeds/head and 100 seed weight (g). Head diameter in both seasons was the supreme (15.82 and 16.09 cm) under wider planting distance (30 cm) between hills. From the perusal of the results in Table 4, it is evident that planting sunflower in wide distance between hills (30 cm) was accompanied with operative increment in each of No. of seeds/head and 100 seed weight in the first seasons and valued as much as 1095 seeds/head and 5.65 g as seed index. Variation in both No. of seeds/head and 100 seed weight in the second seasons due to varying planting distance was inoperative, and the increase in each of seed number/head and seed index due to widing planting distance between hills from 20 to 30 cm was immaterial.

The decrease in head diameter at the distance of 20 cm is due to the increase in the No. of plants per unit area, thus increasing the competition among plants for growth factors, which reflected in the head diameter. The present results are resembled with those noticed by **Soleimanzadeh *et al.* (2010)**.

Providing enough space for plant helps in receiving larger amount of light encouraging more sufficient photosynthesis, and this is contributed to the formation of more seeds. Supremacy of seed number/ head under wide distance of planting may be attributed to the larger head diameter, which is positively reflected in more number of seeds/head. These results run with the findings of **Ahmed and Ahmed (2010).**

Decreasing 100-seed weight with increasing the plant density is attributed to the lack of light intensity, the amount of formed protein and the amount of dry matter accumulated, which led to less seeds weight. This result agrees with what **O'Nill *et al.* (2004)** stated that there is an inverse relationship between seed weight and plant density. The increase in plant density leads to a fierce competition between the formed seeds per unit area, and then a decrease in the net photosynthesis during the effective period of seed filling.

From the results showed in Table 5, the planting distance of 20 cm obtained the highest seed yield (1155.46 and 1319.32 kg/fad.), and the seed yield increased with the increase in plant density due to the increase in No. of plants per unit area despite the decrease in the yield of the individual plant. This result is in agreement with those of **Taghdiri *et al.* (2006)**.

Table 4. Head diameter (cm), No. of seeds/head and 100-seed weight (g) as affected by planting distances and irrigation regimes

Main effects and interaction	Head diameter (cm)		No. of seeds/head		100-seed weight (g)	
Planting distances	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
D_1 (20 cm)	14.23	14.61	956	873	4.30	5.40
D_2 (30 cm)	15.32	16.09	1095	997	4.87	5.62
F test	*	*	*	NS	*	NS
Irrigation regimes (I)						
I_1 (at 50% available water)	16.02 a	16.22 b	1227 a	1096 a	4.81 a	5.7
I_2 (75% of I_1)	15.66 a	19.16 a	1170 a	1042 ab	4.69 a	5.55
I_3 (50% of I_1)	14.44 b	13.32 c	904 b	843 b	4.56 ab	5.4
I_4 (25% of I_1)	13.00 c	12.67 c	800 b	759 bc	4.29 b	5.39
F test	*	*	*	*	*	NS
D × I	*	*	*	*	*	NS

*, ** Significant at 5% and 1% levels of probability, respectively; NS = Not-significant

Table 5. Seed yield (kg/fad.) and WUE (kg/m^3) as affected by planting distances and irrigation regimes

Main effects and interaction	Seed yield (kg/fad.)		WUE (kg/m^3)	
Planting distances	**Season 1**	**Season 2**	**Season 1**	**Season 2**
D_1 (20 cm)	1155.46	1319.32	1.06	1.21
D_2 (30 cm)	995.79	1025.21	0.91	0.94
F test	*	*	NS	*
Irrigation regimes (I)				
I_1 (at 50% available water)	1323.52 a	1424.36 a	0.81 b	0.87 b
I_2 (75% of I_1)	1256.30 a	1310.92 a	0.99 b	1.03 b
I_3 (50% of I_1)	941.17 b	1033.61 b	1.03 b	1.13 b
I_4 (25% of I_1)	773.10 b	920.16 b	1.39 a	1.65 a
F test				
D × I	*	*	*	*

*, ** Significant at 5% and 1% levels of probability, respectively; NS = Not-significant

Effect of irrigation treatments

Irrigation regimes studied acted significantly on head diameter and No. of seeds/head of sunflower in both seasons, while its act was significant on 100-seed weight (g) in the first season only (Table 4). Values of each of head diameter in the first season, No. of seeds/head in both seasons and 100-seed weight in the first season were at par under both of sufficient irrigation at 50 % of soil available water (I_1) and irrigation at 75% of (I_1), that means saving 21.97% of I_1 irrigation regime *i.e.* saving 358.88 m^3 /fad.

Increasing water stress through decreasing irrigation water amount up to 1395 m^3/fad. (I_3) or 697.5 m^3/fad. (I_4) caused operative decrement in each of head diameter, No. of seeds/head and 100-seed weight, these results were veridical in both seasons. These results are in one's line with **Iraj *et al.* (2011)** results.

Water stress in early stages of growth, especially in the stage of transformation from vegetative growth to flowering, has negatively affected the determination of No. of seed origins. That is due to the inhibition in the rate of photosynthesis, and then the lack of preparation of metabolized materials in seed sites, which caused the abortion of fertilized seeds, which also contributed to reducing No. of seeds/head. This result agrees with the results of **Ahmed and Ahmed (2010) and Iraj *et al.* (2011)** who indicated that water stress had a significant effect on No. of seeds/head and attributed this to the small head size.

It has been found that the weight of seeds was affected by water stress during seed-filling phase because of decreasing nutrients supplied to the seed (the rate of dry matter accumulation). This result agrees with the results of many researchers **(Chimenti *et al.*, 2002; Erdem *et al.*, 2006)**.

Seed yield of sunflower under irrigation regimes are publicized in Table 5. Seed yield (kg/fad.) exhibited slight and insignificant reduction (5.08 and 7.96 %) in the 1st and 2nd seasons due to irrigation at 75% (I_2) from the sufficient irrigation at 50% from soil available water (I_1). More water stress through application of irrigation regimes I_3 (irrigation at 50% of I_1) or I_4 (irrigation at 25% of I_1) hampered sunflower productivity and seed yield decreased significantly from 1323.52 to 941.17 then to 773.10 kg/fad. under I_1, I_3 and I_4 irrigation regimes in respective order in the first season. The same trend was noted in the second season. Results in Tables 3 and 4 disclose that sunflower grew healthy under both water irrigation regimes I_1 and I_2, so plants were significantly taller, larger stem diameter with larger leaf area index *i.e.* source capacity of dry matter increased. Affluence of dry matter production and accumulation was with tremendous avail and effectively increased head diameter, No. of seeds/head and seed index which turn into high seed yield.

Paul (1983) indicated that the exposure of plants to water stress leads to a delay in the production of leaves and the emergence of florets for a period of 4: 7 days, which in turn leads to a decrease in the head diameter and seed yield.

Effect of Interaction between Planting Distances and Irrigation Regimes

The effect of interaction between study factors was studied, results expressed in Fig. 2 showed that the interaction took the same trend as the main factors.

Water consumption and water use efficiency

It is noted from Table 5 that the irrigation treatment I_1 recorded the highest value for the amount of irrigation water used, and this is logical due to the increased level of soil moisture, which positively affected the growth characters as it caused an increase in the amount of water lost through evaporation and transpiration. Results also

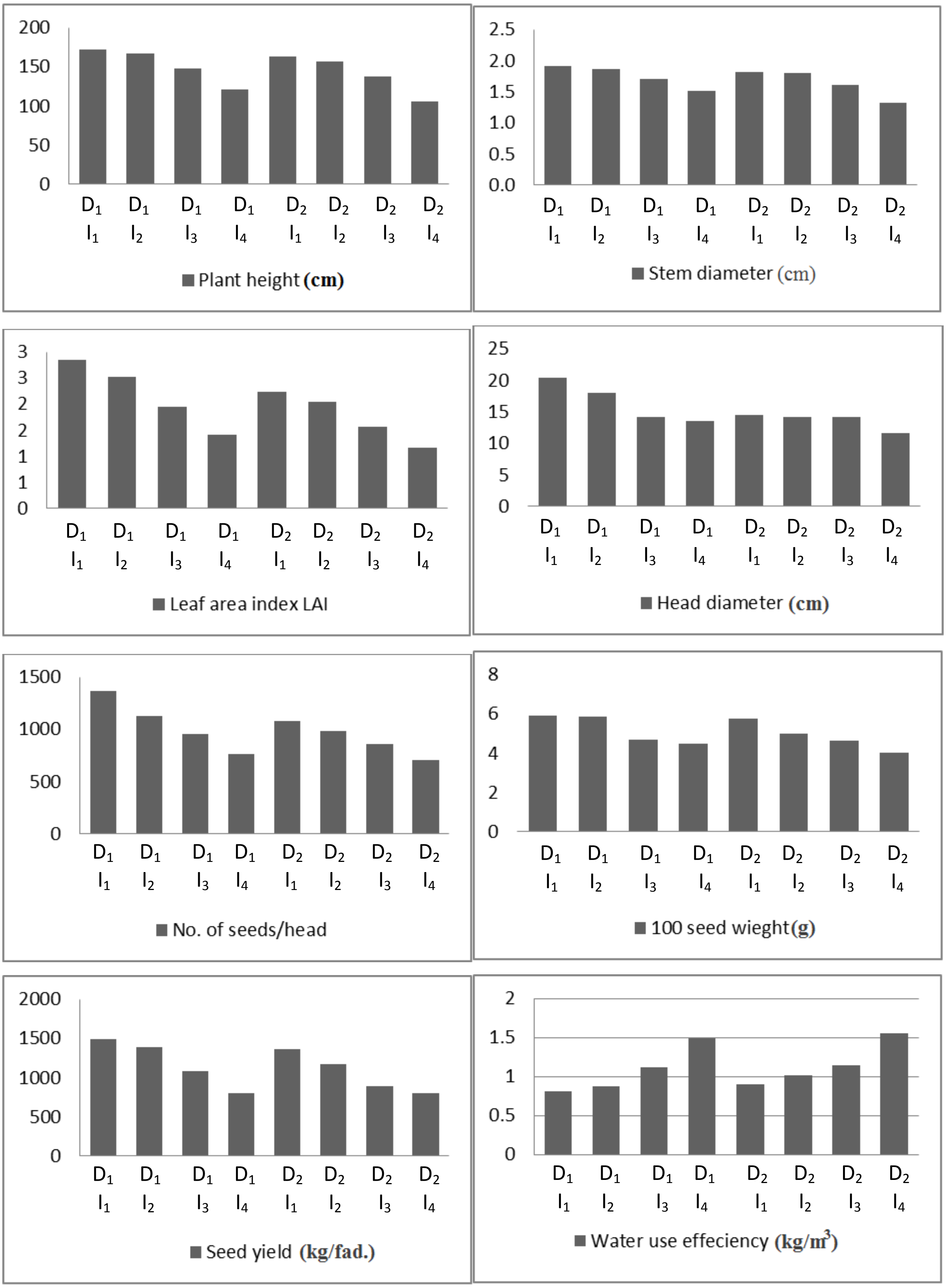

Fig. 2. The effect of interaction between Planting distances and irrigation regimes on studied characters

indicated a significant decrease in seed yield by decreasing the quantities of irrigation water for all treatments except the irrigation treatment I_2 that did not differ significantly from the treatment I_1, which indicates the possibility of saving 21.97% of the full water needed for irrigation, which was estimated about 358.88 m^3/fad. (4200 m^2) and without affecting the seed yield. The maintained water can be used to increase the agricultural area of this crop in the new lands.

It is also noted that the irrigation treatment I_4 recorded the highest water use efficiency (WUE) with an average of 1.39 kg /m^3 in the first season and 1.65 kg/m^3 in the second season. While the irrigation treatment I_1 recorded the lowest average of WUE (0.8 and 0.87 kg /m^3) in the first and second seasons, respectively. The high efficiency of water use by decreasing the quantities of irrigation water may be because the lack of water leads to a decrease in chlorophyll in plant leaves, and consequently the absorbed light energy decreases, as well as leaves area, hence, less water losses *via* transpiration thus increasing the efficiency of water use (**Acosta-Motos *et al*., 2006**).

There was also a significant effect of planting distances on the efficiency of water use in both seasons. The distance 20 cm between plants (30000 plant/fad.) gained the highest WUE (1.06 and 1.21 kg/m^3) in 1st and 2nd seasons, respectively, while the distance 30 cm (20000 plant/fad.) gained 0.91 and 0.94 kg/m^3. The significance difference between the two planting distances is attributed to the low production of large distances from the total seed yield and the consumption of most of the water added in evaporation, as LAI for this distance was low (Table 3). However, the elevation in water use efficiency is notable and significant between regimes, but it is accompanied by a notable significant decrease in seed yield due to the lack of irrigation water from the first regime to the fourth one. Hence, the non significance difference between I_1 and I_2 in yield allude to that I_2 is the best regime to use even if the decrease of WUE is significant.

Conclusion

Egypt has a wide range of its land area (about 94%) is empty and needed to be reclaimed and cultivated by strategic crops which are not sufficient for local consumption *i.e.* sunflower to face the elevated demand of cooking oil and save money, and that comes at the time of water lack and water international problems. Attributed to the before mentioned, this study have been conducted and the results showed the significance of applying irrigation regime to save water and maintain the seed yield without significant lose. In addition, Planting distances, which are translated into densities, contribute to exploit the unit area as much as possible to maximize productivity and also better use of water.

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الملخص العربي

تأثير مسافات الزراعه ونظم الرى على إنتاجية دوار الشمس وكفاءة استخدام الماء

فارس سليمان محمد جمعة ـ عبدالستار عبدالقادر حسن الخواجة

قسم المحاصيل، كلية الزراعة، جامعة الزقازيق، مصر.

لدراسة تأثير الإجهاد المائي وكثافة الزراعة على صفات النمو ومحصول البذور وكفاءة استخدام المياه لنباتات دوار الشمس (*Helianthus annus* L.) تم إجراء تجربتين حقليتين خلال الموسمين الصيفيين 2020 و2021 في تربة سلتيه رملية فى إحدى الحقول الواقعة بمنطقة أبو حماد، محافظة الشرقية، مصر. استُخدم تصميم القطع المنشقة في ثلاث مكررات لتنفيذ الدراسة. تم وضع مسافات الزراعة بين الجور (20 و30 سم) فى القطع الرئيسية، وخصصت القطع الشقية لنظم الري الأربعة (الري عند 50% من الماء المتاح؛ الري عند 75% و50% و25% من المعاملة الأولى 50% من الماء المتاح). أشارت النتائج إلى أن مسافات الزراعة التى يمكن ترجمتها إلى كثافة نباتيه كان لها أثراً معنوياً حيث أدت زيادة كثافة النباتات من 20000 إلى 30000 نبات/فدان (4200 م^2) من خلال تقليص مسافات الزراعة من 30 سم إلى 20 سم بين الجور إلى زيادة كلٍ من ارتفاع النبات، ودليل مساحة الورقة، ومحصول بذور الفدان بالإضافة إلى زيادة كفاءة استخدام المياه. كما أكدت النتائج أن الري عند 50% من الماء الميسر وعند 75% منه لم يختلفا معنوياً حيث أثر على محصول البذور، ودليل مساحة الورقة، وارتفاع النبات، وقطر الساق، وقطر النورة، وعدد البذور/النورة في كلا الموسمين وبالتالي تم توفير حوالي 21.97% (358.88 م3/فدان) من المياه الكاملة اللازمة للري.

الكلمات الاسترشادية: دوار الشمس، الإجهاد المائي، مسافات الزراعة، كفاءة استخدام المياه.

REVIEWERS:
Dr. Mohamed K. Abdel-Fattah | mohammedkamal8@yahoo.com
Dept. Soil and Water, Fac. Agric., Zagazig Univ., Egypt.
Dr. ElMetwaly A. ElMetwaly | agric1973@gmail.com
Dept. Agronomy, Fac. Agric., Cairo Univ., Egypt.