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GROWTH, PHENOLGY AND YIELD OF SUNFLOWER AS AFFECTED BY IRRIGATION INTERVAL AND POTASSIUM FERTILIZER LEVEL

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ABSTRACT

Two field experiments were conducted in 2016 and 2017 summer seasons at Agric. Exp. Res. Sta., Fac. Agric., Cairo Univ. to study the effect of irrigation intervals (I_1: irrigation every 9 days, I_2: every 18 days and I_3: every 27 days) and three potassium fertilizer level, i.e. K_0: control (zero K_2O) , K_1: 50 kg K_2O and K_2: 75 kg K_2O feddan^{-1} on growth, phenology and yield and its components of sunflower. Results of combined data across two seasons showed that significant differences between irrigation intervals were detected in growth, phenology, yield, yield components, seed oil content and oil yield feddan^{-1}. Irrigation every 18 days produced the maximum values of plant height (183.0cm), number of leaves plant^{-1}(19.4), leaf area plant^{-1} (1626 cm), leaf area index (1.81), head diameter (18.0 cm) head weight (359 g),seed yield plant^{-1}(186 g) ,shelling percentage (51.9%), 1000-seed weight (72.5 g), seed yield feddan^{-1}(1228 kg), stover yield feddan^{-1}(4173 kg), biological yield feddan^{-1} (5407 kg), harvest index (22.7%), seed oil content (32.7%) and oil yield feddan^{-1} (398 kg). However, irrigation every 27 days gave the lowest values of all above mentioned traits. Increasing irrigation intervals from 9 to 27 days significantly decreased days to flowering and physiological maturity. Increasing potassium fertilizer from 50 kg K_2O to 75 kg K_2O feddan^{-1} led to increase of growth, yield and its components and also seed oil content. Interaction effect between irrigation intervals and potassium fertilizer level had a significant effect on all studied traits. It could concluded that irrigation every 18 days with 50 kg K_2O feddan^{-1}resulted in the greatest values for the growth, yield, seed oil content and oil yield feddan^{-1} of sunflower.

Key words: ***Sunflower, irrigation interval, Potassium fertilizer, Phenology, Yield, Oil and protein.***

INTRODUCTION

Sunflower (*Helianthu annuus* L.) occupies a prominent place among oilseed crops, as it contributes approximately 12% to global edible oil production (Chaves *et al* 2015). Seed oil content ranged from 24 to 49% and cake contains 25-35% protein (Al-Qubaie 2012). Sunflower oil is rich in unsaturated fatty acids such as oelic and linoleic which represent 90% of total fatty acids and low saturated fatty acids that have essential role in arteries intransigence and high content of E vitamin (Abdel–Motagally *et al* 2010 and Saleh *et al* 2004). Seed oil of sunflower has absorbed the attraction of many farmers because it can be used in human nutrition, industry and as animal fodder (Gokhan and Gokmen 2010). In Egypt, the area under sunflower is approximately 14,280 feddan with an annual production of about 20,000 tonnes and an average productivity of 1400 kg feddan^{-1} (FAO, 2017). The productivity of sunflower differs greatly by varietal differences and also by environmental conditions such as irrigation and soil fertility (Ahmed *et al* 2018). Irrigation water shortage is usually one of the most important reasons for the reduction of seed yield from the land unit area. Low water potential caused by a soil water deficit is one of the major natural limitations of the productivity of natural and agricultural ecosystems, resulting in large economic losses (Buriro *et al* 2015). Boman and Evans (1991) and Buriro *et al* (2015) stated that development of proper water management and irrigation methods can be a common solution for the sunflower cultivation. Moreover, Chatzopoulos *et al* (2000) reported that water saving techniques are the demand of the time that may increase the absorption capability and retention of water in soil and for the fight against water shortage conditions and decrease of negative effects of drought stress. Irrigation every 7 days significantly increased growth and yield of sunflower (Mubarak *et al* 2008, El Naim and Ahmed 2010, Yagoub *et al* 2010). Also, many researchers reported that irrigation regime had a significant effect on phenological, growth and yield traits of sunflower; among of them Langeroodi *et al* (2014), Elsheikh *et al* (2015), El Mantawy and El Bialy (2018) and Yadavi and Hamzeh (2018). Fertilizer application represents an important measure to correct nutrient deficiencies and to replace elements removed in the products harvested, and has been shown to be particularly effective with respect to yield formation (Bakht *et al* 2010). Practically plant can't grow and develop normally without potassium element, so it can contributes in many important physiological processes in plant, for instances, regulation of osmotic pressure of plant cells and it can control the process of opening and closing of stomata. It also has a relationship with synthesis of protein and fats, synthesis of chlorophyll, stimulation of adenosine triphosphate (ATP) formation and photosynthesis, anabolism and metabolism of carbohydrates and translocation of photosynthates. In addition, potassium is used to increase lipids synthesis in oil crops (Al-Taher *et al* 2013 and Alzobay and Hamza 2003). It is also clear from results of many researchers that increased K_2O fertilizer level led to increase of growth, yield, and yield components and also oil and protein percentage (Bakht *et al* 2010, Al-Taher *et al* 2013, Ertifik and Zengin 2015, Chaves *et al* 2015, El-Nasharty *et al* 2017 and Ahmed *et al* 2018).

In the view of the problems stated above, the aim of this research was to investigate the effect of irrigation regime and potassium fertilizer on phenology, growth, yield and its components and seed quality of sunflower.

MATERIALS AND METHODS

Two field experiments were conducted in 2016 and 2017 summer seasons at Agric. Exp. Res. Sta., Fac. Agric., Cairo Univ., Giza, to study the effect of irrigation regime (I_1:irrigation every 9 days, I_2:irrigation every 18 days and I_3: irrigation every 27 days) and three levels of potassium fertilizer (K_0: control, K_1: 50 kg K_2O feddan^{-1} and K_2: 75 kg K_2O feddan^{-1}) on phenology, growth, yield and its components and oil content of the sunflower variety Giza 102. A spilt plot design in a randomized complete blocks arrangement with three replications was used. The three irrigation intervals treatments were randomly assigned in the main plots. The three potassium fertilizer levels were randomly arranged in the subplots. The experimental plot consisted of five ridges spaced 60 cm apart with 4 meters long (12 m^2).

In both seasons, the preceding winter crop was wheat (*Tritivum aestivu*, L.). Experimental soil texture was clay loam (Table 1). Phosphorus was added before ridging at a rate of 150 kg calcium super phosphate (15.5% P_2O_5) feddan^{-1}. Seeds were sown in hills 20 cm apart on 15th May 2016 and 16th May 2017 seasons. After 20 days from sowing, only one healthy plant was remained in each hill. Nitrogen fertilizer was applied at a rate of 60 kg N feddan^{-1} in two equal doses after thinning and at two weeks later. Potassium fertilizer levels were done i.e. K_0: control (zero), K_1:50 kg K_2O feddan^{-1} and K_2: 75 kg K_2O feddan^{-1} in equal doses after thinning and at two weeks later. First irrigation was done after 21 days from sowing and then applied as per studied irrigation intervals (9, 18 and 21 days). Other agricultural processes were done according to normal practice recommended by Oil Crop Research Section, Agricultural Research Center, Ministry of Agriculture, Egypt.

Table 1. Physical and chemical analysis of soil at the experimental site in 2016 and 2017 seasons.

Season	Clay	Silt	Sand	Organic	pH	Salinity	N	P	K	Zn	Fe	Mo	Cu
	%	%	%	%	-	ds.m^{-1}	ppm	ppm	ppm	ppm	ppm	ppm	ppm
2016	38.1	24.5	37.4	1.9	7.8	0.87	39	16.7	198	0.67	13.1	3.4	0.59
2017	38.6	24.3	37.1	1.8	7.9	0.78	38	15.4	201	0.53	12.8	3.2	0.56

Phenology/ growth stages

The following stages in Table (2) represent growth/ development event in terms of number of days for each stage starting from sowing date (Schneiter and Miller 1981). Number of days to each phenology/growth stage was noted when 50% of the plants of each plot in all the replications reached the respective stage. Description of each growth stage was shown in the following Table:

Table 2. Phenological stages of sunflower.

Growth stage	Description
R_1	**The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed directly above the immature bracts from a many-pointed star-like appearance.**
R_4	**The inflorescence begins to open. When viewed from directly above immature ray flowers are visible.**
$R_{5.8}$	**80% of disk flowers are completed (flowering).**
R_9	**Physiological maturity. The bracts become yellow and brown.**

Growth traits

After 60 days from sowing, samples of five guarded plants were taken randomly from the middle ridges of each plot to measure *i.e.* plant height (cm) and number of leaves plant^{-1}. Total leaf area plant^{-1}(LA) and leaf area index (LAI) were estimated using the punch method (Watson and Watson 1953). A sample of 10 leaf disc was taken from leaves along the three plants using a puncture of a known area. The leaves and discs were left to dry in an electric oven, then the dry weight of both was determined. Knowing the weight of leaves and that of disc and the disc area, the leaf area index was determined.

Yield traits

At harvest, five guarded bagged plants were randomly taken from each plot and the following traits were recorded.

1. Head diameter (cm): The head diameter was examined by crosswise measurement of the head exactly through center of the head in centimeters.
2. Stem diameter (cm): The stem diameter was measured at the third internode using a scaled Vernier from the five plants and hence the mean stem diameter for a single plant was recorded.
3. Head weight plant^{-1}(g).
4. Seed yield plant^{-1} (g).
5. Shelling percentage: was calculated by dividing seed yield plant^{-1} by head weight plant^{-1} and multiplying the product by 100.
6. Seed index (g): was estimated by counting 1000-seeds at random from each plot four times and weighed by a sensitive digital balance.
7. Stover yield feddan^{-1}(kg): was obtained from whole area of each plot and then converted into yield feddan^{-1}.

8. Seed yield feddan $^{-1}$ (kg): was obtained from whole area of each plot and then converted into yield feddan^{-1}.
9. Biological yield feddan^{-1} (kg): was estimated by summation of seed yield feddan^{-1} and stover yield feddan^{-1} (kg).
10. Harvest index (%): Harvest index (%) was estimated as ratio of seed yield to biological yield at harvest.
11. Seed oil content (%) was determined according to A.O.A.C. (1995) using Soxhelt apparatus and petroleum hexane as an organic solvent.
12. Oil yield feddan^{-1} (kg): was calculated by multiplying oil% in the seeds by seed yield feddan^{-1} (kg).

Statistical analysis

Data were subjected to analysis of variance of the split plot design according to the procedure outlined by Steel and Torrie (1997). The combined analysis was conducted for the data of the two seasons after testing the error variances homogeneity of both seasons according to Snedecor and Cochran (1990). Treatment means were compared based on Least Significant Differences (LSD) at a probability level of 5%. Finally, all statistical analyses were carried out using "MSTAT-C" program.

RESULTS AND DISCUSSION

1. Growth traits

1.1. Effect of irrigation interval

The effects of irrigation interval and potassium fertilizer on sunflower growth characteristics (plant height, No. of leaves plant^{-1}, leaf area plant^{-1}(cm^2) and leaf area index) at 60 days after sowing (DAS) indicated significant differences in combined data across seasons (Table 3). The frequent irrigation interval (I_1: irrigation every 18 days) significantly increased plant height (183.9 cm), No. of leaves plant^{-1}(19.4), leaf area plant^{-1} (1626 cm^2) and leaf area index (1.81). The longest irrigation interval (I_3: irrigation every 27 days) had a significant reduction in plant height (3.93%), No. of leaves plant^{-1} (12.79%), leaf area plant^{-1}(19.1%) and leaf area index (19.3%) as compared with the irrigation interval of 18 days. This results agreed with that reported by Hang and Evans (1985), Jamro and Larik (1991) and Yagoub *et al* (2010), who found that when moisture stress was imposed during vegetative growth stage, short plant with fewer leaves were developed and also, ealier senescence of leaves were was happened which decreased biomass (Langeroodi *et al* 2014). Our results are in agreement with those reported by Thakuria *et al* (2004), Aziz and Soomro (2001), Yagoub *et al* (2010), El Naim and Ahmed (2010), Bakht *et al*

(2010), Buriro *et al* (2015) and Yadavi and Hamzeh (2018), who observed that plant height, number of leaves plant^{-1}, leaf area plant^{-1} and leaf area index were significantly affected by irrigation frequency.

Table 3. Effect of irrigation interval and potassium fertilizer level on some growth traits of sunflower at 60 DAS in combined data across seasons (2016 and 2017).

Treatments	Growth traits			
	Plant height (cm)	Leaves No. plant^{-1}	Leaf area plant^{-1} (cm^2)	Leaf area index (LAI)
Irrigation interval				
I_1 : every 9 days	177.8	17.2	1522	1.69
I_2: every 18 days	183.9	19.4	1626	1.81
I_3: every 27 days	175.8	18.8	1316	1.46
L.S.D. at 5%	2.34	1.12	42.7	0.18
Potassium fertilizer level				
K_0: Control	176.9	18.3	1430	1.59
K_1: 50 kgfeddan^{-1}	181.1	19.1	1539	1.71
K_2: 75 kg feddan^{-1}	179.4	18.7	1495	1.68
L.S.D. at 5%	2.49	0.43	45.1	0.08

1.2. Effect of Potassium fertilizer

The results presented in Table (3) show that plants fertilized with 50 kg K_2O feddan^{-1} rate of potassium fertilizer had a significant increase in plant height, number of leaves plant^{-1}, leaf area plant^{-1} and leaf area index at 60 DAS as compared with 75 kg K_2O feddan^{-1} and control (unfertilized). This may be due the influence of K on some physiological processes, such as carbohydrate metabolism and formation, breakdown of starch and translocation of sugars (Ahmed *et al* 2018). Also, potassium plays an important role in controlling and regulating the activities of various essential elements and activate many enzymes which in turn affects plant growth (Ahmed and Mekki 2004 and Ahmed *et al* 2018).The differences between K_1 treatment (50 kg K_2O feddan^{-1}) and K_2 treatment (75 kg K_2O feddan^{-1}) did not reach to a significant level for all growth traits at 60 DAS. These results are in conformity with Boulbaba *et al* (2005), Sadras (2006), Asghar *et al* (2007) and Zaki *et al* (2013), who reported that increasing potassium fertilizer level significantly increased all growth characters. On the other hand, Ahmed *et al* (2018) reported that sunflower plants fertilized with 75 kg K_2O feddan^{-1} rate of potassium fertilizer had higher growth vigor than that 50 kg K_2O feddan^{-1} and differences between control and 50 kg K_2O feddan^{-1} were not significant for all growth characters.

1.3. Effect of irrigation interval × potassium fertilizer level

Results in Table (4) indicated that effect of interaction between irrigation interval and potassium fertilizer level on some growth characters at 60 DAS were significant in combined data across seasons. The treatment I_2K_1 gave the highest values of plant height (186.2 cm), number of leaves plant^{-1} (19.8), leaf area plant^{-1}(1698 cm^2) and leaf area index (1.89), whereas minimum value of plant height (174.4 cm), number of leaves plant^{-1}(17.3), leaf area plant^{-1} (1290 cm^2) and leaf area index (1.43) were recorded with (K_0I_3) treatment combination.

Table 4. Effect of interaction between irrigation interval and potassium fertilizer level on some growth traits of sunflower at 60 DAS in combined data across seasons (2016 and 2017).

Irrigation interval*	K Fertilizer level**	Growth traits			
		Plant height (cm)	No. of leaves plant^{-1}	LA plant^{-1} (cm^2)	LAI
I_1	K_0	175.1	18.3	1441	1.60
	K_1	177.8	19.4	1570	1.74
	K_2:	176.5	18.8	1556	1.72
I_2	K_0	182.4	19.2	1560	1.73
	K_1	186.2	19.8	1698	1.89
	K_2:	183.2	19.1	1621	1.80
I_3	K_0	174.4	17.3	1290	1.43
	K_1	179.3	18.2	1350	1.50
	K_2:	178.5	17.9	1310	1.46
LSD at 5%		1.10	0.25	49.2	0.07

***Irrigation interval; I_1 every 9 days, I_2: every 18 days and I_3: every 27 days.**
**** K fertilizer level; K_0: control, K_1: 50 K_2O and K_2: 75 K_2O.**

2. Phenology traits

2.1. Effect of irrigation interval

Results in Table (5) showed that irrigation interval and potassium fertilizer level significantly affected number of days to R_1, R_4, $R_{5.8}$ and R_9 stages of sunflower plants in combined data across seasons. Irrigation every 27 days (I_3) throughout the season led to a significant decrease in number of days to R_1 (32.7 day), R_4 (52 day) , $R_{5.8}$ (62.7 day) and R_9 (92.0 day) than those of sunflower plants irrigated every 9 days throughout the season (I_1) (35.0, 55.0, 65.0 and 96.0 days), respectively.

Table 5. Effect of irrigation interval and potassium fertilizer level on some phenological stages of sunflower in combined data across seasons (2016 and 2017).

Treatments	Phenological stages*			
	Days to R_1	Days to R_4	Days to $R_{5.8}$	Days to R_9
Irrigation interval				
I_1 : every 9 days	35.0	55.0	65.0	96.0
I_2: every 18 days	34.0	54.0	64.0	94.3
I_3: every 27 days	32.7	52.0	62.7	92.0
L.S.D. at 5%	0.87	1.15	1.10	2.14
Potassium fertilizer level				
K_0: Control	34.0	53.7	62.7	93.0
K_1: 50 kg feddan^{-1}	33.0	52.7	64.0	94.0
K_2: 75 kg feddan^{-1}	34.7	54.7	65.0	95.3
L.S.D. at 5%	0.68	1.21	1.21	0.89

*** R_1: Button stage, R_4: inflorescence begins to open, $R_{5.8}$: 80% disk flowers are open (anthesis) and R_9: physiological maturity.**

It is clear that decreasing the irrigation interval with decreasing the irrigation interval, and continuing the water supply up to later crop stage prolonged the period between sowing and studied phenological stages. On the other hand, increasing the irrigation interval and discontinuing the crop irrigation at early stages resulted in physiological changes in sunflower plants and caused earliness in flowering and maturity was recorded. Earliness in days to flowering and physiological maturity may be play an important role for drought escape in sunflower plants under stress conditions. The previous results are in full agreement with those reported by Buriro *et al* (2015), who stated that sunflower irrigated five or four times took more days to maturity.

2.2. Effect of potassium fertilizer

Results presented in Table (5) revealed that potassium fertilizer treatments had a significant effect on days to button stage(R_1: the terminal bud forms a miniature floral head rather than a cluster of leaves), inflorescence begins to open (R_4) , 80% disk flowers are open ($R_{5.8}$) and physiological maturity (R_9) phenological stages in combined data across seasons. Application of 75 kg K_2O feddan^{-1} took highest number of days to all studied growth stages. Increase in number of days to different phenological stages could be attributed to increased vegetative growth (Bakht *et al* 2010). These results are in line with those recorded by Moujiri and Arzani (2003), Sadras (2006) and Bakht *et al* (2010).

2.3. Effect of irrigation interval × potassium fertilizer level

The interactive effect of irrigation interval × potassium fertilizer level was significant on days to button stage button stage (R_1: the terminal bud forms a miniature floral head rather than a cluster of leaves), inflorescence begins to open (R_4), 80% disk flowers are open ($R_{5.8}$) and physiological maturity (R_9) phenological stages in combined data across seasons (Table 6). Maximum number of days to all phenological stages was observed in combination treatment, irrigation every 9 days with application 75 kg K_2O feddan^{-1}(I_1K_2). However, the minimum number of days to all phenological stages was recorded when sunflower plants irrigated every 27 days and without application of potassium fertilizer (I_3K_0) in combined data across seasons.

Table 6. Effect of interaction between irrigation interval and potassium fertilizer level on some phenological stages of sunflower in combined data across seasons (2016 and 2017).

Irrigation interval*	K Fertilizer**	Phenological stages***			
		Days to R_1	Days to R_1	Days to R_1	Days to R_1
I_1	K_0	35	55	64	95
	K_1	34	54	65	96
	K_2:	36	56	66	97
I_2	K_0	34	54	63	93
	K_1	33	53	64	94
	K_2:	35	55	65	96
I_3	K_0	33	52	61	91
	K_1	32	51	63	92
	K_2:	33	53	64	93
LSD at 5%		0.56	0.87	0.81	0.92

*** Irrigation interval; I_1 every 9 days, I_2: every 18 days and I_3: every 27 days.**
**** K fertilizer level; K_0: control, K_1: 50 K_2O and K_2: 75 K_2O**
***** R_1: Button stage, R_4: inflorescence begins to open, $R_{5.8}$: 80% disk flowers are open (anthesis) and R_9: physiological maturity.**

3. Yield and yield components

3.1. Effect of irrigation interval

The results in Table (7) reveal that all yield components were significantly affected by irrigation interval and potassium fertilizer level in combined data across seasons. Irrigation every 18 days (I_2) gave the highest head diameter (18.0 cm), head weight (359 g), seed yield plant^{-1} (186 g) shelling percentage (51.9%), 1000-seed weight (72.5 g), seed yield feddan^{-1} (1228 kg), stover yield feddan^{-1}(4173 kg), biological yield feddan^{-1} (5407 kg), harvest index (22.7%), seed oil content (32.4%) and oil yield feddan^{-1} (398 kg), whereas, the lowest ones were detected from irrigation every 27 days (I_3).

Table 7. Effect of irrigation interval and potassium fertilizer level on yield traits of sunflower in combined data across seasons (2016 and 2017).

Treatments	Yield traits										
Irrigation interval	Head diameter (cm)	Head weight plant^{-1} (g)	Seed yield plant^{-1} (g)	Shelling (%)	1000-Seed weight (g)	Seed yield (kg feddan^{-1}	Stover yield (kg feddan^{-1}	Biological yield (kg feddan^{-1})	Harvest index (%)	Oil (%)	Oil yield (kg feddan^{-1})
I_1 : every 9 days	17.3	347	179	51.3	65.2	1021	4040	5028	20.3	31.6	323
I_2: every 18 days	18.0	359	186	51.9	72.5	1228	4173	5407	22.7	32.4	398
I_3: every 27 days	15.7	329	167	49.6	59.9	989	3854	4843	20.4	32.7	324
L.S.D. at 5%	1.13	69.8	5.1	0.87	3.45	71.6	112.3	142.3	1.16	0.38	14.46
Potassium fertilizer level											
K_0: Control	16.5	334	163	48.8	55.3	893	3673	4566	19.6	31.6	314
K_1: 50 kg feddan^{-1}	18.4	356	186	52.2	68.4	1151	4105	5256	21.8	32.8	378
K_2: 75kg feddan^{-1}	17.1	346	177	51.2	64.0	1094	3988	5055	21.6	32.3	354
L.S.D. at 5%	1.24	54.3	7.8	0.39	1.51	42.6	75.6	89.6	0.31	0.27	18.4

It is obvious that increasing irrigation interval from 18 to 27days significantly decreased head diameter (12.8%), head weight (9.10%), seed yield plant^{-1} (11.4%), shelling percentage (4.64%), 1000-seed weight (21.0%), seed yield feddan^{-1} (24.2%), stover yield feddan^{-1} (8.28%), biological yield feddan^{-1} (11.7%), harvest index (11.3%), seed oil content (2.14%) and oil yield feddan^{-1}(22.8%), respectively. These results may referred to the effect of water deficit, resulted from irrigation at long interval (I_3 treatment), which in turn reduced plant growth and all yield components and consequently seed filling and weight (Abdou *et al* 2014). Also, water stress causes deceleration of cell enlargement and thus reduces stem length by inhibiting intermodal elongation and also checks the tillering capacity of plants (El Mantawy and El Bialy 2018). Similar findings were earlier reported by Yadav *et al* (2009), Yagob *et al* (2010), El Naim and Ahmed (2010), Abdou *et al* (2011), Langeroodi *et al* (2014), Elsheikh *et al* (2015), Buriro *et al* (2015), El Mantawy and El Bialy (2018), and Yadavi and Hamzeh (2018) who reported that water stress had a negative impact on growth parameters, yield and yield components, seed oil content and oil yield of sunflower.

3.2. Effect of potassium fertilizer

Results in Table (7) indicated that in general, increasing potassium fertilizer application significantly affected seed , stover and biological yields as well as yield components (Head diameter, weight of head, 1000-seed weight, shelling percentage, harvest index , seed oil content and oil yield in combined data across seasons. Application of potassium fertilizer rate of 50 kg K_2O feddan^{-1} recorded the highest values of head diameter (18.4 cm), head weight (356 g), seed yield plant^{-1}(186 g), shelling percentage (52.2%), 1000-seed weight (68.4 g), seed yield feddan^{-1} (1151 kg), stover yield feddan^{-1}(4105 kg), biological yield feddan^{-1}(5256 kg), harvest index (21.8%), seed oil content (32.8%) and oil yield feddan^{-1}(378 kg) as compared with other potassium fertilizer rates. These may be due to increase of growth, which in turn reflected positively on yield and its components of sunflower and vital role of potassium in photosynthesis, translocation of photosynthates, protein synthesis, ionic balance, regulation of plant stomata and water use, activation of plant enzymes and many other processes as well (Boulbaba *et al* 2005, Asghar *et al* 2007, Singh and Kataria 2012 and Ahmed *et al* 2018). Similar findings were reported by Omar and Abd El-Hameed (2012), Zaki *et al* (2013), Al-Taher *et al* (2013), Ertiftik and Zengin (2015), Chaves *et al* (2015), El-Nasharty *et al*(2017) and Ahmed *et al* (2018). On the other hand, Bakht *et al* (2010) indicated that oil content was not significantly affected by potassium fertilizer rates.

3.3. Effect of irrigation interval × potassium fertilizer level

Results in Table (8) revealed that the seed yield and yield components were significantly affected by interaction between irrigation interval and potassium fertilizer level; also seed oil content and oil yield feddan^{-1} were significantly affected by the same interaction in combined data across seasons.

Table 8. Effect of interaction between irrigation interval and potassium fertilizer level on yield traits of sunflower in combined data across seasons (2016 and 2017).

Irrigation interval*	K Leve**	Yield traits					
		Head diameter (cm)	Head weight plant^{-1} (g)	Seed yield plant^{-1} (g)	Shelling (%)	1000-Seed weight (g)	Seed yield (kg feddan^{-1})
I_1	K_0	16.9	336	174.3	51.9	62.8	969
	K_1	17.4	361	184.2	50.9	68.6	1105
	K_2:	17.6	346	176.9	51.2	64.3	989
I_2	K_0	17.3	345	183.2	53.1	73.6	1134
	K_1	18.6	372	189.7	50.9	76.4	1289
	K_2:	181	360	185.6	51.6	67.6	1260
I_3	K_0	15.3	321	162.3	50.5	59.4	875
	K_1	16.1	335	169.2	47.5	60.3	1059
	K_2:	15.7	333	168.9	50.8	60.1	1032
LSD 5%		1.10	21.1	2.45	1.58	3.41	79.1

Irrigation interval*	K Leve**	Yield traits				
		Stover yield (kg feddan^{-1})	Biological yield (kg feddan^{-1})	Harvest index (%)	Oil (%)	Oil yield (kg feddan^{-1})
I_1	K_0	3950	4919	19.7	31.1	301
	K_1	4120	5225	21.1	32.4	358
	K_2:	4050	4939	20.0	31.4	311
I_2	K_0	4110	5244	21.6	31.6	358
	K_1	4298	5587	23.1	32.9	424
	K_2:	4110	5390	23.4	32.7	412
I_3	K_0	3860	4757	18.5	32.1	281
	K_1	3898	4957	21.3	33.2	352
	K_2:	3805	4837	21.3	32.9	340
LSD 5%		67.8	94.2	0.31	.29	22.1

*** Irrigation interval; I_1 every 9 days, I_2: every 18 days and I_3: every 27 days.**
**** K fertilizer level; K_0: control, K_1: 50 K_2O and K_2: 75 K_2O**

Irrigation every 18 days with 50 kg K_2O feddan^{-1} fertilizer recorded the highest values of head diameter (18.6 cm), head weight (372 g), seed yield plant^{-1} (189.7 g), shelling percentage (50.9%), 1000-seed weight (76.4 g), seed yield feddan^{-1}(1289 kg), stover yield feddan^{-1}(4289 kg), biological yield feddan^{-1}(5589 kg), harvest index (23.1%), seed oil content (32.9%) and oil yield feddan^{-1}(424 kg) compared with other treatments. These results are in disagreement with those obtained by Chaves *et al* (2015) who reported that the highest rate of potassium fertilizer (120 kg K_2O ha^{-1}) and 100% of available soil water produced the highest production. These results are in line with those obtained by Soleimanzadeh (2010).

CONCLUSION

Sunflower plants are sensitive to both excessive and deficit water which leads to decrease in growth and seed yield. Sunflower plants irrigated every 18 days interval and fertilized with 50 kg K_2O $feddan^{-1}$ resulted maximum values for growth, yield and yield components and took more days to flowering and maturity. However, irrigation every (27 days) without potassium fertilizer reduced sunflower days from sowing to flowering and physiological maturity, plant height, number of leaves $plant^{-1}$, leaf area $plant^{-1}$, leaf area index, head diameter, head weight, seed yield $plant^{-1}$, shelling percentage, seed yield feddan-1, stover yield feddan-1, biological yield $feddan^{-1}$, seed oil content and oil yield $feddan^{-1}$. It was therefore, concluded that irrigation interval of 18 days with potassium fertilizer rate 50 kg K_2O $feddan^{-1}$ was an optimum irrigation regime for achieving higher economical sunflower seed yield.

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نمو وتطور وإنتاجية دوار الشمس تحت تأثير فترات الرى و التسميد البوتاسى

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أجريت تجربتان حقليتان في محطة التجارب والبحوث الزراعية، كلية الزراعة، جامعة القاهرة خلال الموسمين الصيفيين ٢٠١٦ و ٢٠١٧ وذلك لدراسة أستجابة دوار الشمس صنف جيزة ١٠٢ لثلاثة فترات رى (الرى كل ٩ و ١٨ و ٢٧ يوم) و ثلاثة مستويات من التسميد البوتاسى (بدون إضافة و ٥٠كجم بو٢أ للفدان و ٧٥ كجم بو٢أ للفدان) و يمكن تلخيص أهم النتائج على النحو التالى: <u>١–تأثير فترات الرى</u>: كانت هناك فروق معنوية بين فترات الرى على صفات النمو و مراحل النمو و صفات المحصول و مكوناته و ومحتوى الزيت بالبذور و محصول الزيت للفدان خلال التحليل التجميعى لموسمى الدراسة؛ أدت معاملة الرى كل ١٨ يوم إلى الحصول على أعلى القيم لصفات طول النبات (١٨٣سم) و عدد اوراق النبات (١٩,٤) و مساحة أوراق النبات (٣٥٩سم^2) و دليل مساحة أوراق النبات (١,٨١) عند عمر ٦٠ يوم من الزراعة؛ و زيادة عدد الآيام من الزراعة حتى التزهير و النضج الفسيولوجى و إلى زيادة قطر القرص (١٨سم) ووزن القرص (٣٥٩جم) و محصول البذور اللنبات (١٨٦جم) و نسبة التفريط (٥١,٩%) ووزن الـ١٠٠٠ بذرة (٧٢,٥جم) ومحصول البذور للفدان (١٢٢٨ كجم) و محصول القش للفدان (٤١٧٣ كجم) و المحصول البيولوجى للفدان (٥٤٠٧كجم) ودليل الحصاد (٢٢,٧%) و محتوى البذور من الزيت (٣٢,٧%) و محصول الزيت للفدان (٣٩٨ كجم) بينما أدت معاملة الرى كل ٢٧ يوم إلى إنخفاض معنوى فى جميع الصفات السابقة و نقص معنوى فى عدد الآيام من الزراعة حتى مرحلة التزهير و مرحلة النضج الفسيولوجى. <u>٢– تأثير معدلات التسميد بالبوتاسيوم</u>: أظهرت نتائج التحليل التجميعى المشترك لموسمى الدراسة التأثير المعنوى لمعدلات التسميد بالبوتاسيوم على جميع الصفات المدروسة؛ أدت إضافة السماد بالبوتاسى حتى ٥٠ كجم بو٢أ للفدان إلى حدوث زيادة معنوية فى صفات النمو و صفات المحصول ومكوناته السابق ذكرها ؛ مقارنة بباقى معدلات التسميد البوتاسى الأخرى. <u>٣–تأثير التفاعل بين فترات الرى و معدلات التسميد بالبوتاسيوم</u>: أوضحت نتائج التحليل التجميعى المشترك للموسمين التأثير المعنوى لتداخل الفعل بين فترات الرى ومستويات التسميد البوتاسى على صفات طول النبات و عدد أوراق النبات و مساحة أوراق النبات و دليل مساحة أوراق النبات عند عمر ٦٠ يوم من الزراعة و عدد الآيام من الزراعة حتى التزهير و النضج الفسيولوجى و قطر القرص ووزن القرص ومحصول البذور للنبات و نسبة التفريط و ووزن الـ١٠٠٠ بذرة و محصول البذور و القش و البيولوجى للفدان و محتوى البذور من الزيت ومحصول الزيت للفدان. ويتبين من نتائج هذه الدراسة أن زراعة دوار الشمس (صنف جيزة ١٠٢) مع الرى كل ١٨ يوم و التسميد البوتاسى بمعدل ٥٠ كجم بو٢أ للفدان يؤدى إلى زيادة معنوية فى صفات النمو و معظمة محصولى البذور و الزيت (كجم/فدان).

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