Physiological, Biochemical and Agronomic Response of Some Flax Cultivars to Water Deficit under Clay Soil Conditions in North Delta

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ABSTRACT: Water stress is the main abiotic stress that negatively affects crop production. A field investigation was conducted at Sakha Agricultural Research Station during 2018/ 2019 and 2019 / 2020 winter seasons to evaluate the response of five flax cultivars (Sakha 3,Sakha 5,Sakha 6,Giza 11and Giza 12)under three irrigation treatments i.e. three irrigations after sowing irrigation (control treatment), Skipping the 3rd irrigation after sowing irrigation (irrig. 1 treatment) and Skipping 2nd and 3rd irrigation after sowing irrigation (irrig. 2 treatment). A split plot design with four replicates was used in this experiment. Results indicated that chlorophyll a , chlorophyll b , relative water content and proline, were not significalty affected with decreasing number of irrigations to two irrigations after sowing irrigation (irrig1 treatment), while malondialdehyde(MDA)and No.of capsules plant^{-1}were affected significantly. On the other hand irrig2 treatment badly affected all physiological studied characteristics and led to a significant decrease in straw and seed yields of all cultivars under study. It could be recommended with sowing Giza 11or Giza 12 and skipping the third irrigation after sowing irrigation to obtaine a high seed and straw yield with saving irrigation water as well as obtaining the highest productivity of irrigation water for both seed and straw yields (PIWseed and PIW straw).

Keywords: Flax, skiping irrigation, physiology, yield, cultivar.

INTRODUCTION

Flax or linseed is one of the most useful crops; sown for its fiber and oil. In Egypt flax is grown as a dual purpose, where flax fibers are used for textile industry and oil are used in painting and varnish industry. Flax plays important role in national income by flax fibers exporting for hard currency. In recent years, conflicts between population growth, agricultural development, and environmental degradation have come to prominence and that paid the research in crop biology under adverse conditions to be necessary **(Shi et al., 2008).** Water stress is considered as one of the main harsh abiotic stresses that can inhibit the growth, yield and quality of flax. Climate changes increase the risk of water stress **(Begcy et al., 2012 and Dash et al., 2014).** Water stress has negative effects on plant growth through influences on all of the growth, physiology, metabolic activities and biochemical processes of plants (**Islam et al., 2011 and EL Sabagh et al., 2019**). **Sadak and Bakry (2020)** reported that drought stress decreased significantly all growth parameters, photosynthetic pigments, yield and yield components while, a significant increase in proline in flax were observed. Leaf relative water content (RWC) reduced with decrease in available soil water for linseed **Kariuki et al (2016)**. **Farahat et al., (2021)** reported that chlorophyll (chl a and chl b) and relative water contents were decreased under water deficit conditions, while proline content were increased. **Sharma et al., (2012)** found that irrigation at 30 and 60 days after sowing gave high means of growth characters compared with irrigation at 30 days after sowing only. In the other study **El_Shimy (2017)** found that flax plants (Giza 10) irrigated every 21 or 28 days and fertilized with 60 kg N/fad maximized quantity and quality of straw and seed yield characters. **Chorumale et al. (2001)** and **Yenpreddiwar et al. (2007)** indicated that, two irrigations applied at flowering and capsule filling stages significantly increased the yield attributes,yield, oil content and oil yield of flax compared with no irrigation and irrigation at flowering stage only. **Rashwan et al. (2016)** concluded that, irrigation intervals have a significant role on flax production and irrigation every 35 days (4 irrigation) performed the best traits. **EL-Refaey et al (2015)** reported that Giza 10 (fiber type) recorded the highest plant technical length and fiber yield per fed. **Kineber et al (2015)** found that Sakha 5 (oil type) surpassed in straw, seed and oil percentage compared with Sakha2. It is very important to increase flax production per unit area which could be achieved by using high yielding cultivars undr water shortage condetions. Therefore the objectives of this investigation were to evaluate five flax cultivars to find out the more tolerant one under condition of irrigation water shortage to obtain high yield as well as saving water.

MATERIALS AND METHODS

A Field experiment was conducted at Sakha Agricultural Research station (31° 05 N, 30° 55 E), during 2018/019 and 2019/020 seasons to invesigate the effect of some irrigation treatments on five flax cultivars. The experiment was carried out in a Split-plot design in four replicates. The main plots were assigned to three irrigation treatments(Table 1), while the sub plots were allocated to five flax cultivars i.e. (Sakha 3, Sakha 5, Sakha 6, Giza 11 and Giza 12). The soil texture was clay loam according to **Klute** (**1986)**,the mean of electrical conductivity of the soil (ECe) were 3.67 and 3.45 dS m^{-1},for the first and second season respectively, and was determined according to **(Jackson, 1973).** Sowing was carried out on12nd and 15th Novumber in the first and second seasons respectively, using the broadcasting method. The unit of each sub plot was 6 m^2 (2m lenght x3m width). 45 kg N / fed. as nitrogen fertilizer in the form of urea (46.5%) was applied in two equal doses before the first and second irrigation. The remaining cultural practices were applied as recommended in flax fields in this region.

Irrigation treatments:

Irrigation treatments were executed as follows:

(**control**) treatment = Given full irrigation i.e., all irrigations (three irrigations after sowing irrigation).

(**irrig 1**) treatment = Skipping the 3rd irrigation after sowing irrigation

(**irrig 2**) treatment = Skipping 2nd and 3rd irrigation after sowing irrigation

Table 1: Irrigation treatments of flax cultivars during two growing seasons

No.of irrigations / Treatments	Sowing irrigation	Frist irrigation	2nd irrigation	3rd irrigation
control	+	+	+	+
irrig 1	+	+	+	-
irrig 2	+	+	_	_

Studied characteristics

1- **Calculating amount of irrigation applied water (m^3 $fad.^{-1}$):**

Water applied (Wa) was computed as described by **Giriappa (1983)**

$$Wa = IW + Re$$

Where: IW = Irrigation water applied, and Re = Effective rainfall.

Irrigation water was applied to the experimental plots until reaching the end of the plot length. This was measured and delivered by a constant rectangular weir and the rate of discharge was 0.01654 m^3 sec^{-1} at effective head of 10 cm. The amount of water was calculated by the following equation;

$$A = Q X T$$

Where: A = the volume of water delivered to the plot (m^3)

Q = the discharge of the weir (m^3 min^{-1}) and

T = the time of irrigation (minute).

Amount of irrigation water applied (m3 fad.-1):

As shown in Figure 1, there were three irrigation water treatments as follows: control treatment, included the amount of applied water requirements (three irrigations after sowing irrigation) for flax crop, depending on the neighbors' farmers from the experimental areas. it, reached 1250 m3 fed-1 about throughout the winter seasonal (29.8 cm) and 1310 m3 fed-1 (31.2 cm) during both 2018/2019 and 2019/2020, respectively. Irrig 1 (two irrigations after sowing irrigation) from water requirements were 1010 m3 fed-1, (24.0 cm) and 1073 m3 fed-1 (25.5 cm), during the two seasons, respectively. Irrig 2 included one irrigation after sowing irrigation by 710 m3 fed-1 (16.9 cm) and 781 m3 fed-1 (18.6 cm), respectively, in both seasons. Data of AW for every irrigation treatment are the same under the different cultivars for flax treatments.

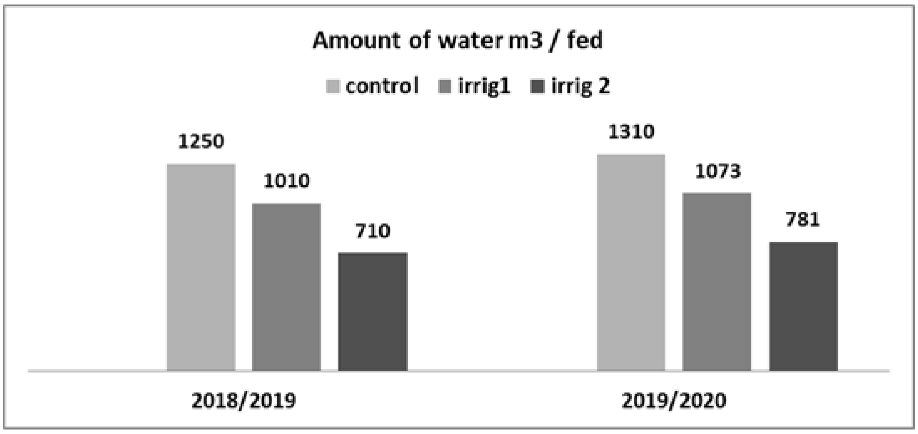

Figure.1. Amount of applied water (AW, m3 fed-1) for flax crop during 2018/019 and 2019/020 seasons for the three aplied irrigation treatments

Physiological and biochemical characteristics:

At flowering stage (90 days after sowing) , ten plants from each plot were randomly taken to determine:

- Chlorophyll content (chl. a and chl. b), leaf sample were homogenized in N-N-Dimethylformamid and chl a and b were determined using the spectrophotometric method at the two wave length 664 and 647 nm, according to **Moran, 1982** using the following formulas

Chl. a = 12.64 A_{664}-2.99 A_{647} (µg ml^{-1})

Chl. b = -5.6 A_{664} + 23.26 A_{647} (µg ml^{-1})

- Relative water content percentage (RWC %) was measured according to **Gonzalez and Gonzalez (2001)** plant leaveswere taken from each plot and weighted as (fresh weigh FW). The leaves were then placed in distilled water for 4 h at 25 °C and their saturated weights (SW) were measured, then were oven dried at 70°C and weighted ,RWC were calculated by following formula:

RWC (%) = (FW- DW) / (SW- DW)*100

- Proline content in flax leaves was determined by homogenizing sample of leaves (0.5 g) with 10 ml Sulphosalicylic acid (3% w/v), and then were filtered using filter papers. 2ml of the supernatant was then added to a test tube with 2 ml Glacial acetic acid and 2 ml freshly prepared Ninhydrin acid solution. The test tubes were incubated in a water bath for 1 h at 100°C and then allowed to cool. 4 ml of toluene were added to the tubes and then mixed for 20 sec. Proline content was measured using Spectrophotometer at wave length 520 nm (**Bates et al., 1973)**.
- **Malondealdehyde (MDA µmols g^{-1} FW**.) the level of lipid peroxidation in plant was estimated according to **Heath and Packer (1968**) and expressed as µmols g^{-1} FW using an extinction coefficient of 155 $mMcm^{-1}$.

At full maturity, ten individual plants were taken randomly from sub plots to estimate :

3- Straw yield and its component:

Technical Length (cm),Stem diameter(mm) and straw yield $plant^{-1}$ (g)

4- Seed yield and its component:

Fruiting zone length (cm),number of capsules $plant^{-1}$ and seed yield $plant^{-1}$ (g).

At harvesting time (140 days after sowing), one square meter of each plot were pulled manually to estimate:

Seed yield $fed^{-1}$and straw yield fed^{-1} **.**

5- Seed chemical composition

- Oil percentage (%)

Random samples of seeds were taken to determine oil percetage according to **AOAC (1990).**

6- Productivity of irrigation water (PIW, kg m^{-3}):

Productivity of irrigation water (PIW) was calculated according to **(Ali et al., 2007)**

PIW = Y/ IW

Where: PIW = Productivity of irrigation water (kg m^{-3}), Y = marketable yield (seed and straw) kg fed^{-1}. and IW = Irrigation water applied (m^3 $fed.^{-1}$)

Statistical analysis

Analysis of variance for split plot design was performed according to **Gomez and Gomez (1984)** using MSTATC computer software. Data means were compared using Duncan's Multiple Range Test according to **Duncan (1955).**

RESULTS AND DISCUSSION

Physiological and biochemical characteristics

Presented data in Table 2 distinctly showed that there is highly significant differences existed among the three irrigation treatments on both chlorophyll pigments (Chl. a and b) in the two studied seasons. Where control treatment gave the highest values of chl.a (7.98 and 8.68 µg ml^{-1}) and chl.b (2.42 and 2.58 µg ml^{-1}) in the first and second seasons respectively with insignificant differences from irrig1 treatment. While irrig 2 treatment (one irrigation after sowing irrigation) caused significant decrease in chl.a and chl.b compared

Table. 2: Mean values of physiological and biochemical characteristics (chl. a, chl b, RWC, proline and MDA) as affected by the three irrigation treatments and the five cultivars of flax in 2018/019 and 2019 / 020 seasons.

Treatments	Chlorophyll a (μg ml^{-1})		Chlorophyll b (μg ml^{-1})		RWC (%)		Proline (mg g^{-1} FW)		MDA (μmol g^{-1} FW.)	
Irrigation treatment(I)	**2018/ 19**	**2019/20**	**2018/ 19**	**2019/20**	**2018/ 19**	**2019/20**	**2018/ 19**	**2019/20**	**2018/ 19**	**2019/20**
Control	**7.98a**	**8.68a**	**2.42a**	**2.58a**	**62.27a**	**63.42a**	**0.233b**	**0.221b**	**190.41c**	**180.62c**
irrig 1	**7.72a**	**8.29a**	**2.26a**	**2.39ab**	**60.14a**	**61.79a**	**0.296ab**	**0.278ab**	**245.04b**	**226.72b**
irrig 2	**6.65b**	**6.01b**	**1.84b**	**2.00b**	**55.23b**	**55.85b**	**0.379a**	**0.324a**	**349.50a**	**322.58a**
F. test	**	**	**	*	**	*	*	*	*	**
Cultivars (C)										
Sakha 3	**6.87c**	**7.16b**	**2.14b**	**2.29bc**	**58.32cd**	**59.99b**	**0.300**	**0.258b**	**295.87a**	**272.80a**
Sakha 5	**6.53d**	**6.83c**	**2.06b**	**2.16c**	**56.50d**	**57.47c**	**0.319**	**0.291a**	**236.56c**	**225.40c**
Sakha 6	**7.66b**	**7.84b**	**2.15b**	**2.34b**	**59.19bc**	**60.26b**	**0.283**	**0.265ab**	**275.36b**	**256.70b**
Giza 11	**7.88b**	**8.06a**	**2.12b**	**2.28bc**	**60.63ab**	**61.58ab**	**0.299**	**0.268ab**	**249.05c**	**231.50c**
Giza 12	**8.30a**	**8.40a**	**2.39a**	**2.55a**	**61.44a**	**62.48a**	**0.312**	**0.291a**	**251.40c**	**229.40c**
F. test	**	*	**	**	**	**	**NS**	*	**	*
Interaction										
I x C	**	**	**NS**	**NS**	**	**	**NS**	**NS**	**NS**	**NS**

*, ** and NS indicate $P < 0.05$, $P < 0.01$, and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

with control treatment in both seasons. These resuls were in agreement with those obtained by **Sadak and Bakry (2020) and Farahat et al. (2021),** where they reported that drought stress significantly decreased chlorophyll content. The decrease in chlorophyll contents under water stress conditions may be fundamentally due to chloroplasts injuries caused by the reactive oxygen species (ROS) which formed under water stress conditions **(Shalaby et al., 2020),** where it causes and accelerates leaf senescence **Nowsherwan et al., (2018)** and leaf senescence leads to significant decrease in photosynthesis process. The chlorophyll content could be used to assess stress tolerance of genotypes **(Farahat et al., 2021).**

Data also indicated that decreasing number of irrigations to only one irrigation after sowing irrigation (irrig 2) compared with control treatment (three irrigations after sowing irrigation) led to significant decrease in RWC % of leaves. At the same time decreasing the irrgation only one irrigation (irrig1)treatment (two irrigation after sowing irrigation) didn't affect RWC % of leaves in both seasons. Relative water content decreasing under water stress conditions may be due to both transpiration and the decrease in available soil water

These results were in line with those recorded by **Kariuki et al (2016)** on linseed and **Farahat et al., (2021)** on wheat. RWC represented plant water status and it is considered an important dehydration stress tolerance characteristic **(Dehnavi et al., 2017)** where the water shortage in plant cells impacts badly on all physiological and biochemical processes(**EL Sabagh et al., 2019)** consequently affecting plant growth and development. Also, the decrease in RWC is followed by stomata closure **(Zhao et al., 2020**) consequently decreasing co_2 concentration which affects photosynthetic processes **(Cornic 2000)**.With regard to proline content data in Table 2 clearly showed that proline content increased significantly with increasing water stress conditions where the highest values of proline (0.379 and 0.324 mg g^{-1}FW) were noticed at one irrigation after sowing irrigation (irrig 2 treatment) in the two seasons respectively,while the lowest one (0.233 and 0.221 mg g^{-1} FW) were obtained from normal irrigation(control treatment) in the first and second seasons respectively. Proline plays an important role in adaptation of cells to various adverse environmental conditions through raising osmotic pressure in the cytoplasm, stability of proteins and membranes, and maintaining the relatively high water content obligatory for plant growth and cellular functions **(Elewa et al. 2017and Sadak and Bakry 2020).** Data of Malondialdehyde content (MDA) are presented in Table 2 , the highest values of lipid peroxidation by-products malondyaldehyde (349.50 and 322.50 μmol g^{-1} FW) were obtained from the least amount of irrigation water (irrig 2 treatment) in the first and second seasons respectively. On the contrary normal irrigation (control treatment) gave the lowest and favarable values of MDA(190.41 and 180.62 μmol g^{-1} FW) in the two seasons respectively. Water stress induces oxidative stress to cell membranes and malondealdehyde (MDA) is the final product of membranes lipid peroxidation. MDA analysis facilitates genotypes evaluation in plant breeding research **(Labudda 2013),** where cultivars that produce a little amount of MDA under water stress are considered more tolerant to these conditions as reported by **Saeidi et al., 2017**. Haighly significant diffrences were observed among the five cultivars on physiological and biochemical characteristics(Table 2) where, Giza 12 recorded the highest concentrations of both chl. a (8.30and 8.40 µg ml^{-1}) and chl.b (2.39 and 2.55 µg ml^{-1}) in the two seasons respectively, followed by Giza 11 and Sakha 6 with insignificant diffrences between them. While Sakha 5 recorded the lowest values of chl.a (6.53 and 6.83 µg ml^{-1}) and chl.b (2.06 and 2.16 µg ml^{-1}) and ranked last in both seasons respectively. Also Giza 12 had the highest ratio of relative water content (61.44 and 62.48 %) followed by Giza 11 (60.63 and 61.58 %) in the first and second seasons respectively. On the contrary Sakha 5 recorded the lowest ratio of relative water content and ranked last (56.50 and 57.47%) in the two seasons respectively,the cultivar which had the highest percent of RWC is more suitable to cultivate under water stress conditions.

Sakha 5 and Giza12 recorded the highest content of proline in the two seasons and ranked first, while Sakha3 had the lowest values in the two seasons (Table 2). Concerning MDA,the lowest and favarable values of MDA content were obtained from Sakha5, Giza12 and Giza 11while Sakha 3 and Sakha 6 recorded the highest values. **Saeidi et al., 2017** and **Farahat et al., (2021)** reported that water stress tolerance genotypes had higher RWC, proline and lower content of malondialdehyde (MDA).

Straw yield and its components

Data in Table 3 showed highly significant differences among irrigation treatments on technical length , main steam diameter ,straw yield, where (control treatment) three irrigations after sowing irrigation gave the highest means with no significant differences from two irrigation after sowing irrigation in both seasons. These results may be due to optimum supply of moisture surrounding the root zone which improved the nutrient uptake and translocation, and intimately linked with the plant growth and development. While the lowest values were obtained with skipping the second and third irrigation after sowing irrigation (irrig 2 treatment). These results could be due to the reduction of plant growth which occurs a result of water stress. These results are in agreement with those reported by **EL-sabagh et al., (2015a 2015 b)** ,**AbdEl-Wahed et al., (2015)** ,**Barutcular et al (2016)** reported that water stress cause a reduction in flax growth. **Rashwan et al., (2016)** mentioned that irrigation every 35 days form sowing gave the maximum values for straw and seed yields and their components, while the lowest means for above mentioned were recorded by irrigation every 45 DAS.

Table 3. Mean values of straw yield and its related characters as affected by the three irrigation treatments and the five cultivars of flax in 2018/019 and 2019 / 020 seasons.

Treatments	Technical length (cm)		Stem diameter (mm)		Straw yield (g plant^{-1})		Straw yield (t fed^{-1}.)	
Irrigation treatment (I)	**2018/019**	**2019/020**	**2018/ 019**	**2019/020**	**2018/019**	**2019/020**	**2018/019**	**2019/020**
Control	**84.65 a**	**88.6 a**	**2.44 a**	**2.56 a**	**0.937 a**	**1.215 a**	**3.592 a**	**3.817 a**
irrig 1	**83.80 a**	**87.3 a**	**1.99 ab**	**2.50 a**	**0.863 a**	**1.062 ab**	**3.466 a**	**3.593 a**
irrig 2	**77.40 b**	**82.7 b**	**1.90 b**	**2.14 b**	**0.524 b**	**0.718 b**	**2.564 b**	**2.780 b**
F -test	**	**	*	**	**	**`	**	**
Cultivars (c)								
Sakha3	**83.4b**	**87.9 b**	**1.49 b**	**1.30 a**	**0.417c**	**0.523 d**	**2.916c**	**3.303 c**
Sakha 5	**66.4c**	**70.3 c**	**1.74 b**	**1.48 b**	**0418c**	**0.979 c**	**2.073d**	**2.419 d**
Sakha 6	**86.5a**	**90.5ab**	**2.38 a**	**2.99 a**	**0.975b**	**1.062 bc**	**3.418b**	**3.566 bc**
Giza 11	**87.4a**	**91.9 a**	**2.55 a**	**3.25 a**	**0.993b**	**1.130 b**	**3.555 b**	**3.672 b**
Giza 12	**86.0a**	**90.3 ab**	**2.40 a**	**2.97 a**	**1.066a**	**1.298 a**	**4.073a**	**4.023 a**
F.Test	**	**	**	**	**	**	**	**
Interaction								
I x C	**NS**	**NS**	**NS**	**NS**	*	*	*	*

*, ** and NS indicate P < 0.05, P < 0.01, and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Torky (2020) indicated that control treatment (three irrigation after sowing irrigation) and irrig1 treatment (two irrigations after sowing irrigation) recorded higher straw yield per plant as well as per fad. ,number of capsule per plant and seed yield per fad. Highly significant differences were detected among flax cultivars in both seasons whereas Sakha 6, Giza 11and Giza 12 gave the highest technical length, while Sakha 5 gave the lowest technical length. Giza 12 cultivar was superior in straw yield plant^{-1} as well as straw yield fed^{-1} followed by Giza 11 and Sakha 6. while, Sakha 5 gave the lowest straw yield plant^{-1} and fed^{-1}. Thinner steam diameter was recorded for Sakha3 followed by Sakha 5. These results might be attributed to the differences in their genetic constitution. These results were in agreement with those of **EL-Refaey et al (2010)** and **(2015), El-Seidy et al (2010),Abo-Kaied et at (2015),Leilah et at (2010) ,Kineberet al (2015), Rashwan et al 92016) and Torky (2020) .**

Seed yield and its components

Highly significant effects of irrigation treatments were observed on seed yield and its related components (Table 4), where control treatment gave the highest mean values in fruiting zone length, number of capsule plant^{-1} and seed yield plant^{-1} as well as per fad. and oil percentage. The differences between control treatment and irrig1 treatment (two irrigations after sowing irrigation) were insignificant for above mentioned characteristics.

This could be ascribed to sufficient and favorable moisture condition at critical physiological stage of initiation of flowering and seed filling, where water stress leads to hamper flowering and the developing of flower to capsule and its occurrence during flower and capsule formation results in capsules. These results are in harmony with those by **Leilah et al (2010)**, and **Istanbulluoglu et al., (2015)** and **Rashwan et al., (2016).**

Table 4 : Mean values of seed yield , its components and oil % as affected by the three irrigation treatments and the five cultivars of flax in 2018/019 and 2019 / 020 seasons.

Treatments	Fruiting zone length (cm)		Number of capsules $plant^{-1}$		Seed yield (g $plant^{-1}$)		Seed yield (kg fed^{-1})		Oil (%)	
Irrigation treatment(I)	2018/019	2019/020	2018/019	2019/020	2018/019	2019/020	2018/019	2019/020	2018/019	2019/020
Control	20.65 a	24.30 a	25.10 a	27.95 a	0.406 a	0.418 a	448.25 a	584.30 a	41.00 a	41.10 a
irrig 1	19.35 a	22.35 a	17.70 b	22.75 b	0.389 a	0.406 a	439.55 a	533.90 a	40.25 b	40.85 a
irrig 2	15.00 b	18.00 b	13.60 c	17.90 c	0.302 b	0.303 b	382.05 b	456.90 b	36.25 c	37.80 b
F. Test	**	**	**	**	**	**	**	**	**	**
Cultivars (c)										
Sakha3	11.42 c	14.33 c	9.58 c	14.57 d	0.287 d	0.315 c	352.50 d	425.75 c	31.92 d	3200 c
Sakha 5	19.75 ab	22.83 b	18.58 b	23.58 bc	0.338 c	0.353 b	428.75 bc	515.08 b	44.66 a	44.58 a
Sakha 6	20.75 a	24.42 a	22.75 a	24.42 a	0.411 b	0.418 a	457.25 ab	561.08 ab	40.33 b	41.08 b
Giza 11	21.33 a	24.50 a	24.58 a	26.41 ab	0460 a	0.445 a	47333 a	575.25 a	40.41 b	41.00 b
Giza 12	18.42 b	22.00 b	18.50 b	22.33 c	0.333 c	0.346 bc	404.58 c	548.00 a	38.50 c	41.00 b
F.Test	**	**	**	**	**	**	**	**	**	**
Interaction I x C	NS	NS	*	*	*	*	*	*	NS	NS

*, ** and NS indicate P < 0.05, P < 0.01, and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Data in Table 4 showed also highly significant differences among flax cultivars. Giza 11 cultivar was the superior one for seed yield and it's components. Giza 11 and Sakha 6 surpassed in seed yield fed^{-1} in the first season, while Giza 11 recorded higher seed yield fed^{-1} in both seasons. The highest oil % was detected for Sakha 5 in both seasons. The variation in seed yield and its components among flax cultivars may be due to the genetic differences. Similar results were noticed by **El-Seidy et al (2010), EL-Refaey et al (2010), Abo-kaied et al (2015) Kineberet al (2015), Rashwan et al (2016) and Torky (2020).**

Interaction effect

Figure 2 (A&B) revealed that only Giza12 and Giza 11 in the first season and all cultivars in the second season under normal irrigation (control treatment) recorded the highest concentrations of Chl.a. while the lowest values were obtained from Sakha 5 with irrig 2 (one irrigation after sowing irrigation) in both seasons. Fig 3 (A &B) also illustrated that the highest RWC % were obtained from control treatment with Giza 12 and Giza 11in the first season and irrig1 treatment with either Giza 12 or Giza 11 didn't differ significantly with control treatment in the second season.

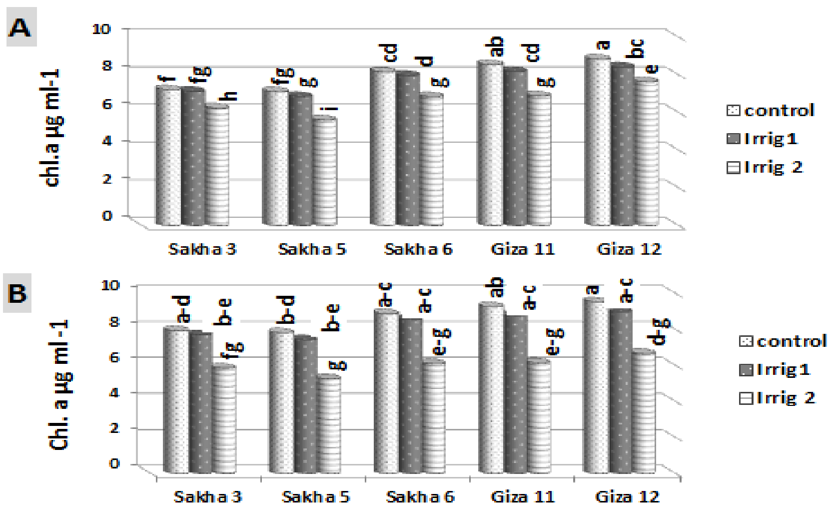

Figure 2(A & B) Interaction effect between three irrigation treatments and five flax cultivars on Chl. a in 2018/ 019 (Fig.A) and 2019/ 020 seasons (Fig. B)

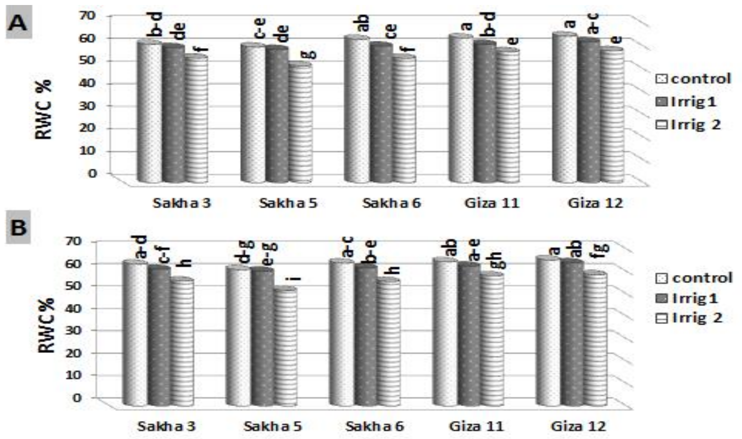

Figure 3(A & B) Interaction effect between three irrigation treatments and five flax cultivars on RWC % in 2018/ 019 (Fig.A) and 2019/ 2020 seasons (Fig. B).

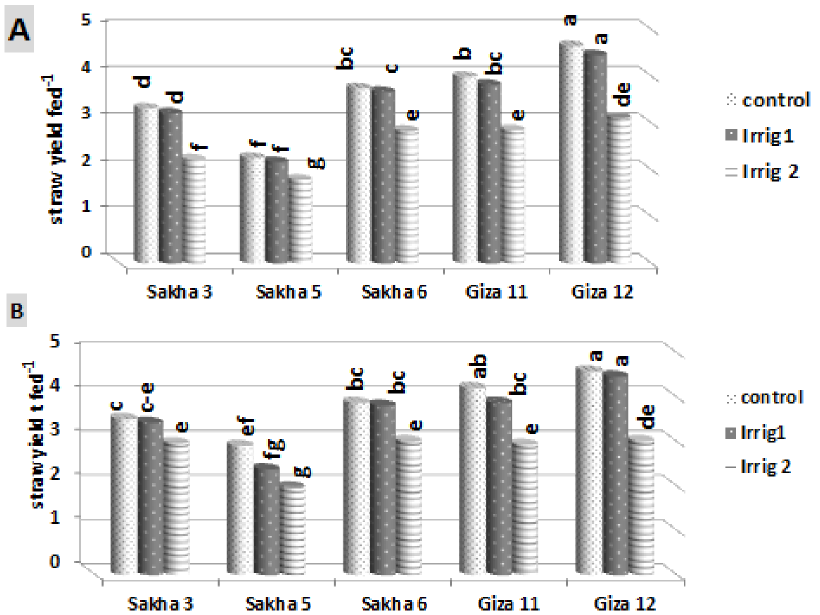

Figure 4 (A &B) Interaction effect between three irrigation treatments and five flax cultivars on straw yield t fad.-1 in 2018/ 019 (A) and 2019/ 020 seasons (B).

The interaction between irrigation treatments and flax cultivars was significant in straw yield / plant and straw yield / fed. Fig.3. whereas the highest values were recorded by four irrigations (control treatment) or two irrigations after sowing irrigation (irrig 1) with Giza 12 cultivar (4.650 and 4.582 t fad^{-1}) and (4.455 and 4.470 t fad^{-1})in both seasons respectively. While the lowest straw yield per plant as well as per fad. were noticed by one irrigation after sowing irrigation (irrig 2) with Sakha 5 cultivars. These results revealed that cultivars differ significantly in their response to irrigation treatment .These differences among cultivars could be due to genetic factors. These results were in agreement with those obtained by **Rashwan et al., (2016) and Torky (2020).**

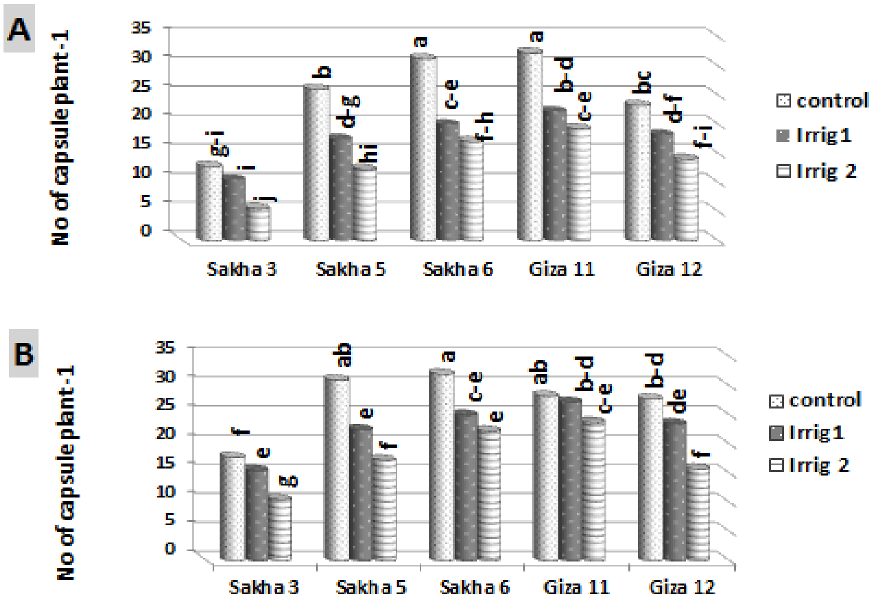

Figure 5 (A &B) Interaction effect between irrigation treatments and flax cultivars on No of capsul plant^{1} in 2018/ 019 (A) and 2019/ 020 seasons (B).

The interaction between irrigation treatments and flax cultivars was significant in number of capsule plant^{-1} and seed yield per fad. in both seasons. The highest number of capsules per plant were obtained by Sakha 6 under normal irrigation (control treatment) in both seasons, with insignificant differences with Giza 11 and Sakha5 under the same conditions as shown in Figure 5. While the highest seed yield fad^{-1} was obtained by Giza 11under either control treatment or irrig 1 treatment (two irrigations after sowing irrigation) (Figure 6).

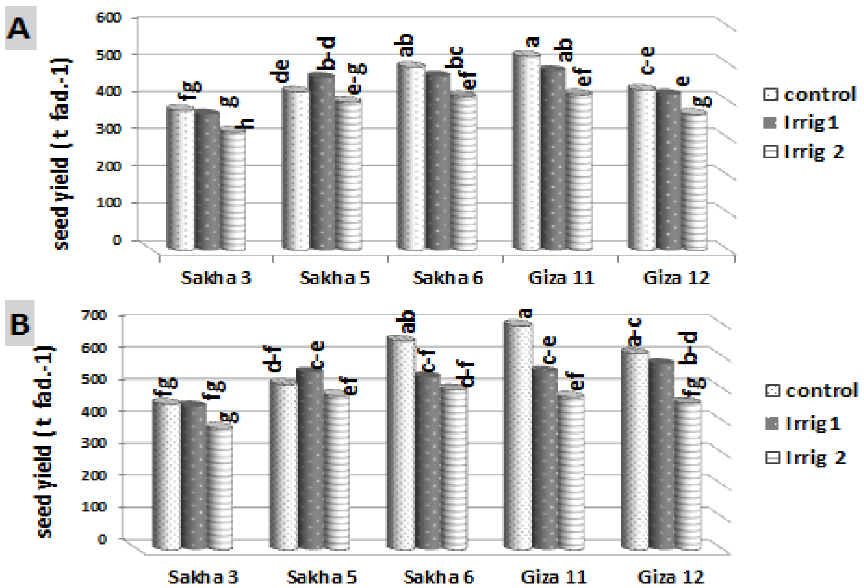

Figure 6 (A &B) Interaction effect between three irrigation treatments and five flax cultivars on seed yield kg fad.$^{-1}$ in 2018/ 019 (Fig.A) and 2019/ 020 seasons (Fig. B).

Productivity of irrigation water (PIW, kg m^{-3})

Productivity of irrigation water (PIW) depended on seed yield (PIW_{seed})and straw yield (PIW_{straw}). The data in Table 5 showed hat the values two seasons for PIW were affected by both irrigation water treatments and flax cultivars treatments. In connection with the effect of irrigation treatments, the highest values were registered with irrigation treatment irrig 2 (skipping the third irrigation after sowing) in the two seasons (0.538 and 0.528 kg m^{-3}, respectively. While, the lowest values were under control treatment (three irrigations after sowing irrigation) In the two seasons 0.359 and 0.446 kg m^{-3} for PIW_{seed}, respectively. Generally, the values for PIW_{seed} in the two seasons and PIW_{straw} in the first season can be descended in order irrig 2> irrig 1> control, but the values for PIW_{straw} in the first season can be descended in order irrig 1> irrig 2> control, respectively. Concerning, the effect of flax cultivars, the highest values for PIW_{seed} were recorded for Giza 11, PIW_{straw} by Giza 12 in the two seasons.

Tv able 5. Effect of irrigation water treatments and flax cultivars on productivity of irrigation water (PIW) in 2018/19 and 2019/20 seasons.

Characteristics	PIW_{seed} (Kg m^{-3})		PIW_{straw} (Kg m^{-3})	
	2018/19	2019/020	2018/019	2019/020
Irrigation treatments				
Control	0.359c	0.446	2.874c	2.914
irrig 1	0.435b	0.498	3.431b	3.349
irrig 2	0.538a	0.528	3.611a	3.217
F. test	**	NS	**	NS
Cultivars				
Sakha3	0.370d	0.399c	2.987c	3.126b
Sakha 5	0.453b	0.486b	2.160d	2.233c
Sakha 6	0.479ab	0.525a	3.543b	3.326b
Giza 11	0.494a	0.534a	3.665b	3.397ab
Giza 12	0.424c	0.509ab	4.173a	3.717a
F. test	**	*	**	*
Interaction				
I x C	*	*	*	*

*, ** and NS indicate $P < 0.05$, $P < 0.01$, and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Interaction effect

Interaction efffect between irrigation treatments and flax cultivars are illustrated in Fig. 7&8. Results showed that the best treatment for PIW_{seed} was irrig.2 treatment with Giza11 ,Sakha6 and Sakha 5, while irrig 2 treatment for Giza 12 recorded the highest $PIW_{straw.}$ in the two seasons. Increasing PIW_{seed} and PIW_{straw} for irrig. 2 with Giza 11 resulted in decreasing amount of water applied for irrig. 2 and increasing seed yield for Giza 11 and straw yield for Giza 12 compared with the other cultivars.

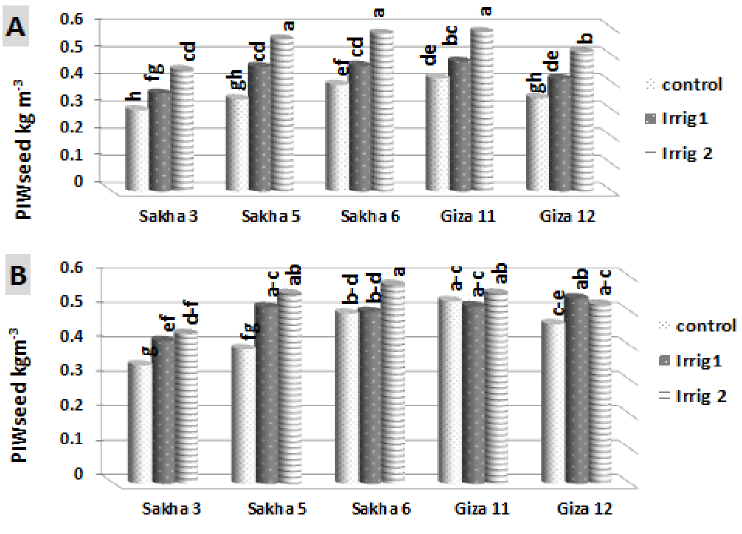

Figure 7 (A &B) Interaction effect between three irrigation treatments and five flax cultivars on PIW_{seed} kg m^{-3} in 2018/2019 (Fig.A) and 2019/2020 seasons (Fig. B).

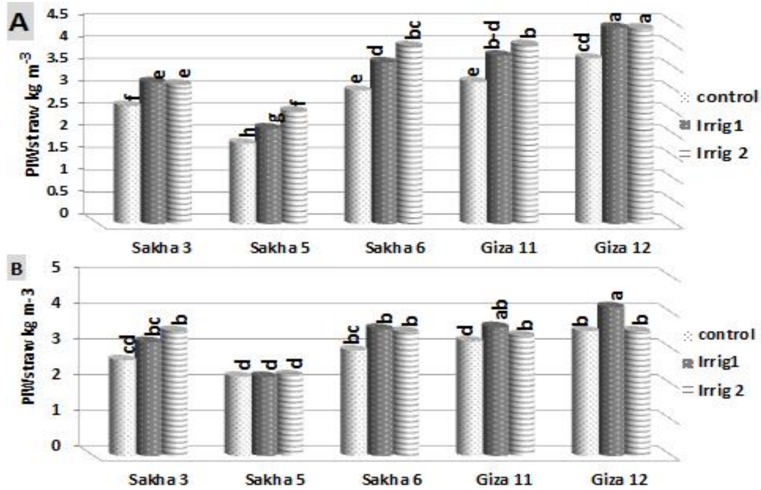

Figure 8 (A &B) Interaction effect between three irrigation treatments and five flax cultivars on PIW straw kg m-3 in 2018/2019 (Fig.A) and 2019/2020 seasons (Fig. B).

CONCLUSION

Based on the results of this investigation, it could be concluded that, irrigation treatments had significant effects on all physiological and yield and its components traits, where control treatment and irrig 1 treatment (two irrigations after sowing irrigation) gave the highest means for chl a, chl.b and relative water content %, straw yield per fad as well as seed yield per fad. Giza 12 cultivar was superior in chl a ,chl b ,RWC and straw yield per fad. While Giza 11 recorded the highest seed yield per fad. it is recommend to plant Giza 12 and use (two irrigations after sowing irrigation) to obtain the highest straw yield fad^{-1},and Giza11 cultivar to obtain the highest seed yield fad^{-1} under clay soil in north Delta.

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الملخص العربي

الاستجابة الفسيولوجية والبيوكيمائية والمحصولية لبعض أصناف الكتان لنقص المياه تحت ظروف الاراضي الطينية بشمال الدلتا

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الإجهاد المائي هو الإجهاد غير الحيوي الرئيسي الذي يؤثر سلبًا على إنتاج المحاصيل. تم إجراء تجربه حقليه بمحطة البحوث الزراعية بسخا خلال موسمي شتاء 2018/ 2019 و 2019/2020 لتقييم استجابه خمسة أصناف من الكتان (سخا 3 ، سخا 5 ، سخا 6 ، جيزة 11 وجيزة 12) تحت ثلاث معاملات ري ((ثلاثة ريات بعد ريه الزرعه كمعاملة تحكم) ،معامله الري 1 (الري مرتين بعد ريه الزراعه مع اسقاط الريه الثالثه) ومعامله الري 2 (الري مره واحده بعد ريه الزراعه مع اسقاط الريه الثانيه والثالثه بعد ريه الزراعه)). أشارت النتائج إلى أن الكلوروفيل أ ، والكلوروفيل ب ، والمحتوى المائي النسبي والبرولين ، لم تتأثر معنويا مع انخفاض عدد الريات لريتين بعد ريه الزراعه (معاملة الري 1) ، بينما تأثر مالونديالديهيد (MDA) وعدد الكبسولات للنبات معنويا. من ناحية أخرى أثرت معاملة الري 2 تاثيرا سلبيا على جميع الصفات الفسيولوجية المدروسة وأدت إلى انخفاض معنوي في محصول القش والبذور لجميع الأصناف قيد الدراسة. يمكن التوصية بزراعة جيزة 11 أو جيزة 12 مع اسقاط الريه الثالثه بعد ريه الزراعه للحصول على اعلي محصول من القش والبذور مع توفير مياه الري والحصول على أعلى إنتاجية من مياه الري للبذور والقش والزيت .