Journal of Agricultural Science; Vol. 8, No. 10; 2016
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Yield and Quality Traits of Some Flax Cultivars as Influenced by Different Irrigation Intervals

Emad Rashwan[1], Ahmed Mousa[2], Ayman EL-Sabagh[3] & Celaleddin Barutçular[4]

[1] Department of Agronomy, Faculty of Agriculture, Tanta University, Egypt

[2] Fiber Crops Research Section, Field Crops Research Institute, Egypt

[3] Department of Agronomy, Faculty of Agriculture, Kafrelsheikh University, Egypt

[4] Department of Field Crops, Faculty of Agriculture, Cukurova University, Turkey

Correspondence: Ayman EL-Sabagh, Department of Agronomy, Faculty of Agriculture, Kafrelsheikh University, Egypt. E-mail: ayman.elsabagh@agr.kfs.edu.eg

Received: July 12, 2016 Accepted: August 22, 2016 Online Published: September 15, 2016

doi:10.5539/jas.v8n10p226 URL: http://dx.doi.org/10.5539/jas.v8n10p226

Abstract

Flax is a potential winter crop for Egypt that can be grown for both seed and fiber. The study was conducted during two successive winter seasons of 2013/14 and 2014/15 in the experimental farm of El-Gemmeiza Agricultural Research Station, Agriculture Research Centre, Egypt. The objective of this work was to evaluate the effect of irrigation intervals (25, 35 and 45) on the straw, seed, oil, fiber yields and quality of flax cultivars (Sakha1, Giza9 and Giza10). Irrigation intervals significantly influenced all studied traits except oil percentage. Irrigated flax plants every 35 days gave the maximum values for all traits, while irrigation every 45 days gave the minimum values. In respect to cultivars, significant differences were found in most yield and quality characters. Furthermore, the performance of Sakha 1 cultivar was superior in main stem diameter, biological, straw yields per faddan, seed index, seed, oil yields per faddan and oil percentage. Meanwhile, Giza 10 cultivar highly significantly out yielded Giza9 and Sakha1 in plant height, fiber fineness, fiber length, total fiber percentage and fiber yield per faddan. The interactions between irrigation intervals and flax cultivars were highly significant for all traits. Based on the results, Sakha1 cultivar recorded the maximum values for main stem diameter, biological, straw yields per faddan, seed, oil yields per faddan and oil percentage and Giza 10 recorded the maximum values for plant height, fiber fineness, fiber length, total fiber percentage and fiber yield per faddan under irrigation of plants every 35 days.

Keywords: flax, fiber, irrigation intervals, oil, straw, seed yield

1. Introduction

Flax (*Linum usitatissimum* L.), is one of the most versatile and useful crops and has been grown for thousands of years (Genser & Morris, 2003). Its oil types known as linseed considered one of the most important oil crops for the extraction of oil. About 80% of the linseed oil goes for industrial purpose and the remaining 20% is used for edible purposes (Asgharipour & Rafiei, 2010). It is a multi-purpose crop with benefits extending to both human and animal nutrition (Szilgyi, 2003). This reflects its very high content of essential fatty acids (EFAs), a high percentage of dietary fiber, and the highest level of "lignans" from any plant or seed products used for human food (Pandey & Agarwal, 1998). Flax is considered one of the most important dual purpose crops for oil and fiber production in Egypt and also in the world, rich in oil (41%), protein (20%), and dietary fiber (28%), (Bakry et al., 2012). Flax is an important economic crop which plays a role in our policy through its local fabrication as well as exportation. Although, the cultivated area in Egypt is relatively small and decreased dramatically in last decade, great reduction had happened in flax cultivated area (Aermae, 2007).

Many researchers found significant differences among the fiber, dual purpose and oil types of flax such as: El-Refaey et al. (2015), where they found that, Giza 10 cultivar (fiber type) gave the highest values for plant height, technical stem length, fiber fineness, fiber length, total fiber percentage and fiber yield per faddan compared with other dual purpose and oil types cultivars. El-Seidy et al. (2015) also inferred that, Line 22 (oil type) gave the highest values for number of fruiting branches per plant, number of capsules per plant, number of seeds per capsule, fertility percentage, seed yield per faddan, oil percentage and oil yield per faddan compared with other dual purpose and fiber types cultivars. In addition, Bauer et al. (2015) mentioned that, the higher fiber contents along with the higher straw yields resulted in the fiber-type cultivars yielding 60-70% more fiber than the seed-type cultivar. However, the seed-type cultivar had higher seed weight and seed yield than the fiber-type cultivar. Flax cultivars significantly differed in yield and its attributes (El-Kady et al., 1995; Abo-Zaid, 1997). Many investigators reported significant differences among flax cultivars concerning straw, seed, oil and fiber yields and their components (El-Hariri et al., 2004; El-Hariri et al., 2012; Barky et al., 2014).

Concerning to irrigation intervals, Chorumale et al. (2001) and Yenpreddiwar et al. (2007) mentioned 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. In addition, Sharma et al. (2012) indicated that, irrigation at both 30 and 60 days after sowing (DAS) produced the highest values of growth characters compared with irrigation at 30 DAS only. Lisson and Mendham (2000) found that, irrigation increased flax straw and seed yield when precipitation was low and with poor distribution. Bauer and Frederick (1997) conducted a two-year study on flax in adjacent irrigated and rainfed areas and found the irrigated flax had approximately 1000 kg ha^{-1} higher straw yield.

It is necessary to increase flax productivity per unit area which could be achieved by using high yielding cultivars and improving the agricultural treatments (El-Sahrawi et al., 2008; Barky et al., 2013; El-Hariri et al., 2012). Therefore, in the recent years many efforts were devoted to increase the productivity of the flax through improving genetic traits and use of improved cultivars which have high yields and high water use efficiency. The cultivars and irrigation intervals were considered two of the main factors that affecting directly the growth and productivity of flax plants. With keeping the above points in view, the objective of this research were to evaluate the performance and response of some flax cultivars under different irrigation intervals.

2. Material and Methods

2.1 Plant Material and Procedures

The present investigation was carried out at El-Gemmeiza Agriculture Research Station, Gharbiua Governorate, Egypt during the two successive winter seasons of 2013/14 and 2014/15 to study the performance and response of some flax cultivars to different irrigation intervals and their influences on straw, seed, oil and fiber yields and its components and quality attributes for these cultivars. The preceding crop was maize (*Zea mays*) in both seasons. The soil texture was clay loam, pH 7.7 and EC 0.40 in both seasons. Precipitation in the experiments area-generally didn't exceed potential evapotranspiration for most crops. As a result, all crops in this area get its needs of water by irrigation, especially surface irrigation. Worthy to mention that, average of precipitation for this experimental location was about 42 mm/m^2 in the winter seasons.

Field experiment was carried out each season using a split-plot design with three replications, and the irrigation intervals were plotted in the main plots. Three irrigation intervals were applied as follows: (25, 35 and 45 days) started after the first irrigation, which means (5, 4 and 3 irrigation times) taking into consideration the sowing and first irrigations. These irrigation intervals are frequently used by farmers under surface irrigation system in the fields of the surrounding areas. However, flax cultivars (Sakha 1, Giza 9 and Giza 10) were arranged in the sub-plots, where each sub-plot size was 6 m^2 (2 m × 3 m) or (1/700 fad.). The two experiments were sown on 27 and 29 October in the first and second season, respectively. Calcium super phosphate was added at the rate of 100 kg/faddan (15.5% P_2O_5) before sowing and potassium sulphate (48% K_2O) was applied in one dose at the rate of 50 kg/faddan before sowing in both seasons. Nitrogen was added to the sub-plots at the rate of 60 kg N/faddan in the form of urea (46% N) in two equal doses, the first half was added before the first irrigation and the second one was added before the second irrigation. Other recommended cultural practices for growing flax were done as usual in the area.

2.2 Sampling and Measurement

Ten individual plants were chosen randomly at full maturity for each sub-plot to record plant height (cm), main stem diameter (mm) and seed index (gm), while other traits were taken from whole plants of the plot.

2.2.1 Straw Yield and Its Related Characters

Plant height (cm): the distance from the cotyledonary node to the top of plant, main stem diameter (mm): at the middle region to the nearest 0.1 mm by using biocles, biological yield per faddan (ton) (faddan = 4200 m^2): estimated all plants from the sub-plots and converted to record biological yield per faddan before removing the capsules, and straw yield per faddan (ton): estimated from the sub-plots and converted to record straw yield per faddan after removing the capsules.

2.2.2 Seed Yield and Its Related Characters

Seed index (gm): It was determined as the average weight of 1000 seeds obtained from each sub-plot, seed yield per faddan (kg): seed yield of an area of each plot (6 m^2) was estimated and transformed to kg per faddan, oil percentage (%): was determined as described by the (AOAC, 1990) methods, using petroleum ether (40-60 °C) in Soxhlet apparatus and oil yield per faddan: was calculated from the following formula: Oil yield per faddan = oil percentage × seed yield per faddan

2.2.3 Fiber Yield and Its Technological Characters

Fiber Fineness (N.m) determined using Radwan and Momtaz (1966) method according to the following equation:

$$N.m = (N \times L)/W \tag{1}$$

Where, N.m = Metrical number, N = Number of fibers (20 fibers and the length for each one = 10 cm), L = Length of fibers in mm (10 cm), and W = Weight of fibers in mg.

Fiber yield per faddan (Kg): calculated from plot fiber yield, Fiber length (cm): Ten fiber ribbons from each treatment were spreaded out and each ribbon was measured then the average fiber length was recorded, Total fiber percentage: It was calculated from the following formula:

$$\text{Total fiber percentage} = \frac{\text{Fiber yield}}{\text{Straw yield after retting}} \times 100 \tag{2}$$

2.3 Statistical Analysis

Using Michigan State University Computer Statistical Package (MSTATC), the analysis of variance was used for the two experiments according to Snedecor and Cochran (1982). The data was statistically analyzed for each season and the homogeneity of experimental error in both seasons was tested, then the combined analysis of data was performed for the characters over two seasons (Le Clerg et al., 1962) to present the main factors and its first and second order interactions. The least significant difference (LSD) test at 0.05 and 0.01 levels of significance was used to indicate mean comparison.

3. Results and Discussions

3.1 Straw Yield and Its Related Characters

The analysis of variance for the combined data with regard to plant height, main stem diameter, biological and straw yields per faddan showed highly significant differences among the three tested irrigation intervals as has presented in Table 1. It was observed that, irrigation every 35 days (4 irrigation times during the growth season) increased plant height, main stem diameter and straw yield per faddan and recorded the highest values for these traits followed by the irrigation every 25 days (5 irrigation times) which ranked the second. While the lowest values for all above mentioned traits were recorded by irrigation every 45 days (3 irrigation times). The only noticeable change in the data direction was irrigation every 25 days (5 irrigation times) recorded the highest values of biological yield per faddan with no significant difference with irrigation every 35 days (4 irrigation times). These results may be due to the reduction of plant growth which occurs as results for some responses to water deficit (irrigation every 45 days) from one side, and excess moisture (irrigation every 25 days) from the other side.

Table 1. Means of straw yield and yield traits as affected by irrigation intervals (combined data)

Irrigation intervals	Plant height (cm)	Main stem diameter (mm)	Biological yield (ton)/faddan	Straw yield (ton)/faddan
I1 every 25 days	96.74	0.9150	4.710	3.848
I2 every 35 days	101.4	0.9672	4.700	4.244
I3 every 45 days	85.11	0.7744	3.821	3.342
$LSD_{0.01}$	0.3203	0.001118	0.07909	0.06126

It is known that, there is a decrease in the photochemical activity of photosynthesis, rubisco enzyme activity and the accumulation of secondary metabolites when plants are under water deficit stress as well as abscisic acid and solutes increase due to water reduction. These factors reduce stomatal conductance and consequently photosynthetic activity which ultimately resulted in a reduction in the synthesis of proteins and cell walls, as well as a decrease in the rate of cell expansion (Chavarria & dos Santos, 2012). On the other hand, flax plant has a shallow rooting system and needs adequate water in the 0-10 cm soil layer (Wood, 1997), and under excess moisture conditions, oxygen was often in short supply, normal exchange of gases from roots to soil was frequently disturbed and altered plant metabolism. Moreover, lodging was more pronounced under excess water conditions especially with high sowing rates. The sum of these responses contributes to explain the reduction of plant growth under excess moisture conditions. These results are in harmony with those obtained by Gabiana (2005) when he reported that, straw and total dry matter production was increased by irrigation compared with rainfed plants. Islam et al. (2011), Ahmadizadeh (2013), El sabagh et al. (2015a, 2015b), Abd El-Wahed et al. (2015a), and Barutçular et al. (2016) revealed that, drought stress causes a reduction in plant growth. De Carvalho et al. (2005) observed an increase in the plants height with increasing the water availability. Taiz and Zeiger (2006) stated that, lesser water availability tends to present lesser plant height, because the water restriction can affect the metabolic processes of growth. Flax is sensitive to water shortage and plant height reduced due to lack of water (Ahlawat & Gangaiah, 2009), Mirshekari et al. (2012) mentioned that, the highest plant height, biological yield and harvest index of flax were obtained from control irrigation treatment, while limited irrigation stress resulted in the lowest these traits.

In this study, the analysis of variance for the combined data showed highly significant differences among the three tested flax cultivars Sakha 1, Giza 9 and Giza 10 (Table 2). It was observed that, Giza 10 cultivar gave the tallest plants and recorded the highest values of plant height. However, Sakha 1 cultivar ranked the first and recorded the highest values of main stem diameter, biological and straw yields per faddan, followed by Giza 10 only in main stem diameter trait, while Giza 9 ranked the second in biological and straw yields per faddan. The present results are mainly due to the genetic differences and potentiality between the fiber and dual-purpose cultivars of flax. Sakha 1 (dual-purpose type) recorded the thicker stem diameter and surpassed other cultivars in seed yield and consequently surpassed it in biological and straw yields. However, Giza 10 (fiber type) gave the tallest plants.

Table 2. Means of straw yield and yield traits as affected by flax cultivars (combined data)

Cultivars	Plant height (cm)	Main stem diameter (mm)	Biological yield (ton)/faddan	Straw yield (ton)/faddan
Sakha 1	90.68	1.047	4.960	4.294
Giza 9	91.44	0.8017	4.289	3.827
Giza 10	101.1	0.8078	3.981	3.312
$LSD_{0.01}$	0.2064	0.0009323	0.05896	0.05106

These results are in good agreement with those obtained by Assar (2008), El-Refaey et al. (2010) and El-Refaey et al. (2015), where they indicated that, fiber types were superior in total height compared with dual-purpose and oil types. However, dual and oil types surpassed fiber types in main stem diameter, biological and straw yields per faddan. El-Refaey et al. (2009) also reported that, ideal fiber types are characterized by the thin stem diameter.

The effect of the first order interactions between (seasons × irrigation intervals), (seasons × flax cultivars) and (irrigation intervals × flax cultivars) on straw yield and its traits are presented in Figure 1. The interaction between seasons and irrigation intervals had only significant effect on main stem diameter and straw yield per faddan. Moreover, the interaction between seasons and flax cultivars had highly significant effect on main stem diameter. While, the effect of the interaction between irrigation intervals and flax cultivars on plant height, main stem diameter biological and straw yield per faddan was highly significant and Giza 10 cultivar recorded the highest plant height under irrigation every 35 days. Whereas, Sakha 1 cultivar recorded the highest main stem diameter, biological and straw yields per faddan under irrigation every 35 days.

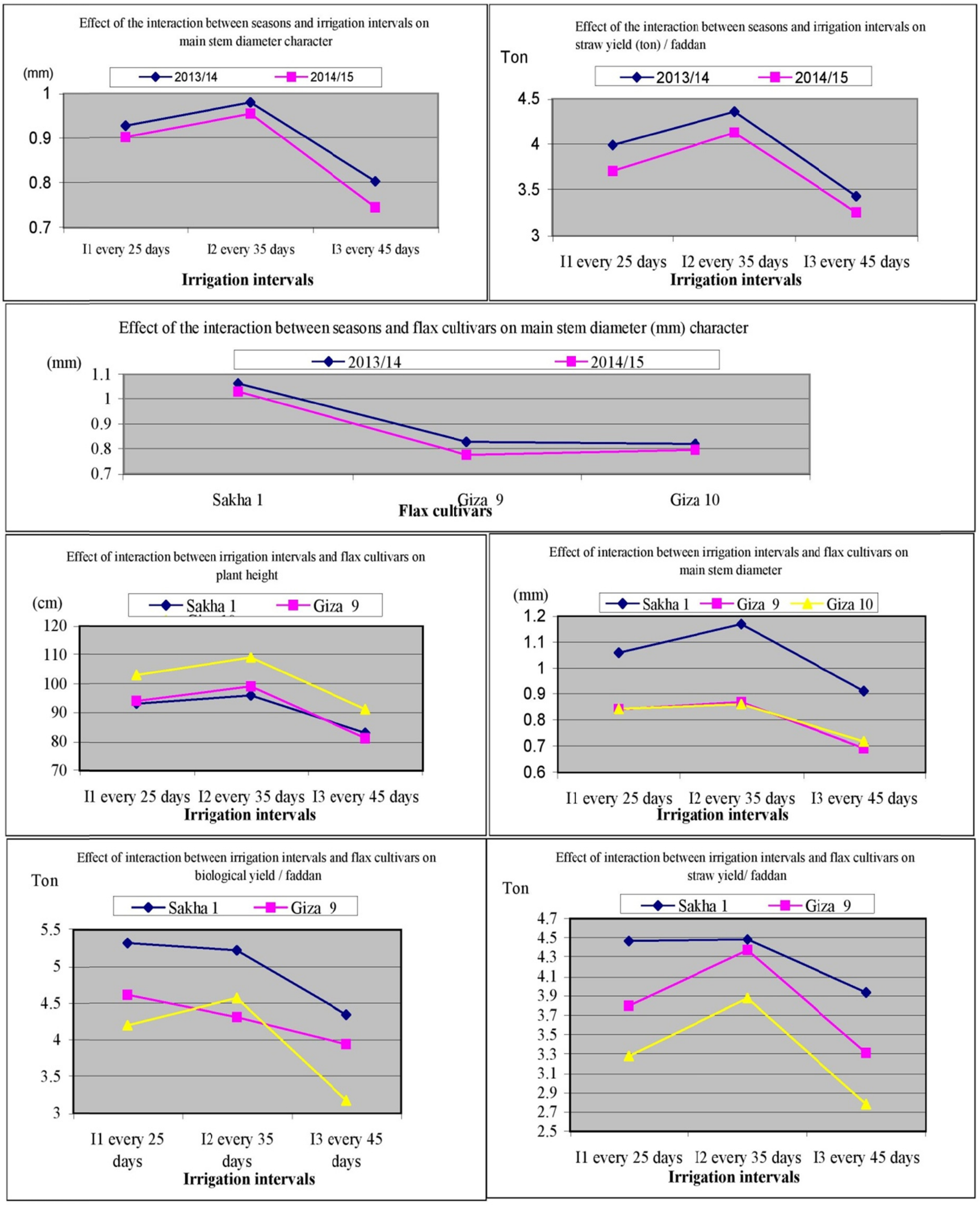

Figure 1. Effects of the first order interactions (seasons × irrigation intervals), (seasons × flax cultivars) and (irrigation intervals × flax cultivars) on straw yield and its traits

The effect of the second order interaction (seasons × irrigation intervals × flax cultivars) on plant height, main stem diameter and straw yield per faddan was highly significant (Table 3), and Giza 10 cultivar recorded the highest plant height under irrigation every 35 days in the first season. Sakha 1 cultivar recorded the highest main stem diameter and straw yield per faddan under irrigation every 35 days in the first season.

These results clearly indicated that, the cultivars significantly differed in their responses to the irrigation intervals. Results revealed that, the variability among tested flax cultivars which may be expected due to the differences of these cultivars in origin, growth habit and genetic constituent and the environmental conditions.

Table 3. Interaction effects among seasons, irrigation intervals and flax cultivars on straw yield and is traits

Seasons	Irrigation intervals	Flax cultivars		
		Sakha 1	Giza 9	Giza 10
Plant height (cm)				
2013/14	I1 every 25 days	93.60	94.70	103.6
	I2 every 35 days	96.50	99.22	109.7
	I3 every 45 days	83.35	81.60	91.60
2014/15	I1 every 25 days	92.60	93.36	102.6
	I2 every 35 days	95.41	99.02	108.7
	I3 every 45 days	82.62	80.77	90.70
$LSD_{0.01}$		0.5055		
Main stem diameter (mm)				
2013/14	I1 every 25 days	1.070	0.8633	0.8500
	I2 every 35 days	1.190	1.190	0.8600
	I3 every 45 days	0.9300	0.7300	0.7500
2014/15	I1 every 25 days	1.050	0.8200	0.8367
	I2 every 35 days	1.150	0.8500	0.8633
	I3 every 45 days	0.8933	0.6567	0.6867
$LSD_{0.01}$		0.02284		
Straw yield per faddan (ton)				
2013/14	I1 every 25 days	4.588	3.931	3.451
	I2 every 35 days	4.693	4.465	3.923
	I3 every 45 days	3.945	3.421	2.923
2014/15	I1 every 25 days	4.344	3.664	3.112
	I2 every 35 days	4.274	4.280	3.828
	I3 every 45 days	3.922	3.203	2.636
$LSD_{0.01}$		0.1251		

3.2 Seed Yield and Its Related Characters

The analysis of variance for the combined data with regard to seed index (gm), seed yield per faddan, oil percentage and oil yield per faddan showed highly significant differences among the three irrigation intervals (Table 4). Irrigation every 35 days (4 irrigation times during the growth season) was achieved the highest values for all previous mentioned traits without significant differences with both irrigation every 25 days (5 irrigation times) for seed index trait and irrigation every 45 days (3 irrigation times) for oil percentage. In addition, irrigation every 25 days (5 irrigation times) ranked the second, while irrigation every 45 days (3 irrigation times) recorded the lowest values and ranked the last for seed yield and oil yield per faddan. The best result for all these traits were obtained from irrigation every 35 days (4 irrigation times). It could be ascribed to favorable moisture conditions resulting from irrigations at critical physiological stages of initiation of flowering and seed filling. Adequate moisture may also increase photosynthesis which is responsible for carbohydrate formation, seed filling and final seed yield. On the other hand, it appears that water stress hampered flowering and reduced the probability of developing flower to capsule and its occurrence during flowering and capsule formation resulted in capsule abortion.

Table 4. Means of seed yield and yield traits as affected by irrigation intervals (combined data)

Irrigation intervals	Seed index (gm)	Seed yield per faddan (Kg)	Oil percentage (%)	Oil yield per faddan (Kg)
I1 every 25 days	6.744	364.4	32.55	119.3
I2 every 35 days	6.746	406.1	33.04	134.4
I3 every 45 days	5.611	327.1	32.90	107.7
$LSD_{0.01}$	0.0353	3.916	0.2694	1.207

These results are in agreement with those obtained by Gabiana (2005), when he found a significant positive effect on seed yield attributed to higher capsule numbers and more seeds per capsule under adequate water conditions. Meanwhile, flax plants subjected to water stress performed poorly in biomass production and yield. Mirshekari et al. (2012) mentioned that, the highest number of primary branches per plant, capsules number per plant, seed numbers per capsule, seed and oil yields per faddan and oil percentage of flax seed were obtained from control irrigation treatment, while limited water stress during flowering and seed filling stages resulted in lowest these traits. Bauer et al. (2015) inferred that, irrigation significantly increased seed weight, although it did not significantly impact on flax seed yield and the average of seed yield under irrigation was higher than rainfed condition.

The analysis of variance for the combined data with regard to seed index (gm), seed yield per faddan, oil percentage and oil yield per faddan as affected by the three tested flax cultivars Sakha 1, Giza 9 and Giza 10 are presented in Table 5. A highly significant variation was found among cultivars, and Sakha 1 cultivar recorded the highest values for all these traits, followed by Giza 9 cultivar with no significant differences between them only for oil percentage. However, the lowest values were recorded by Giza 10. These differences among the tested cultivars could be mainly attributed to the differences in their genetical construction and their response to the environmental conditions. The marked differences in seed index are mainly due to the differences in genetical make up of the tested cultivars. In addition, the variations among cultivars in seed yield per faddan and oil percentage are mainly due to the genetical variation possessed by the tested cultivars, and the increment in seed yield per faddan for Sakha 1 is attributed to the increase of number of capsules per plant, number of seeds per capsule (unpublished data) and seed index. Consequently, the increment in oil yield per faddan for Sakha 1 is attributed to the increment in seed yield per faddan and oil percentage.

Table 5. Means of seed yield and yield traits as affected by flax cultivars (combined data)

Cultivars	Seed index (gm)	Seed yield per faddan (Kg)	Oil percentage (%)	Oil yield per faddan (Kg)
Sakha 1	7.741	545.7	33.19	181.1
Giza 9	5.824	284.7	33.15	94.34
Giza 10	5.536	267.1	32.15	86.00
$LSD_{0.01}$	0.02948	5.719	0.07800	2.003

Such results are in harmony with those reported by Zahana et al. (2003), El-Azzouni et al. (2003), Kineber (2004) and Abou-Zaied and Mousa (2007), where they found that, Sakha 1 flax cultivar significantly produced the highest values of capsules number per plant, seed index, seed yield per faddan, oil percentage and oil yield per faddan compared with other tested dual-purpose and fiber cultivars. El-Seidy et al. (2010) and El-Seidy et al. (2015) reported that, flax oil types realized the highest seed yield per faddan, oil percentage and oil yield per faddan followed by dual purpose types, while the lowest values were recorded by fiber types. Bauer et al. (2015) concluded that, the seed-type cultivar had higher seed weight and seed yield than the fiber-type cultivar. The differences between the tested cultivars could mainly be attributed to the differences in their genetical constitution and their response to the environmental conditions. In this connections, many investigators obtained higher levels of varietal differences in yield and its components in many regions (Kineber et al., 2006; El-Kady Eman & Abd El-Fatah, 2009; Abd El-Wahed et al., 2015b; EL Sabagh et al., 2016a, 2016b).

The effect of the first order interactions (seasons × irrigation intervals) and (irrigation intervals × flax cultivars) on seed yield and its traits are presented in Figure 2. The interaction between seasons and irrigation intervals had only significant effect on seed yield per faddan and oil yield per faddan. While, the effect of the interaction between irrigation intervals and flax cultivars had highly significant effect on all seed traits, and Sakha 1 cultivar recorded the highest value for seed index under irrigation every 25 days. Moreover, the same cultivar recorded the highest values for oil percentage, seed yield per faddan and oil yield per faddan under irrigation every 35 days, with no significant differences with irrigation every 25 days for the last two mentioned traits.

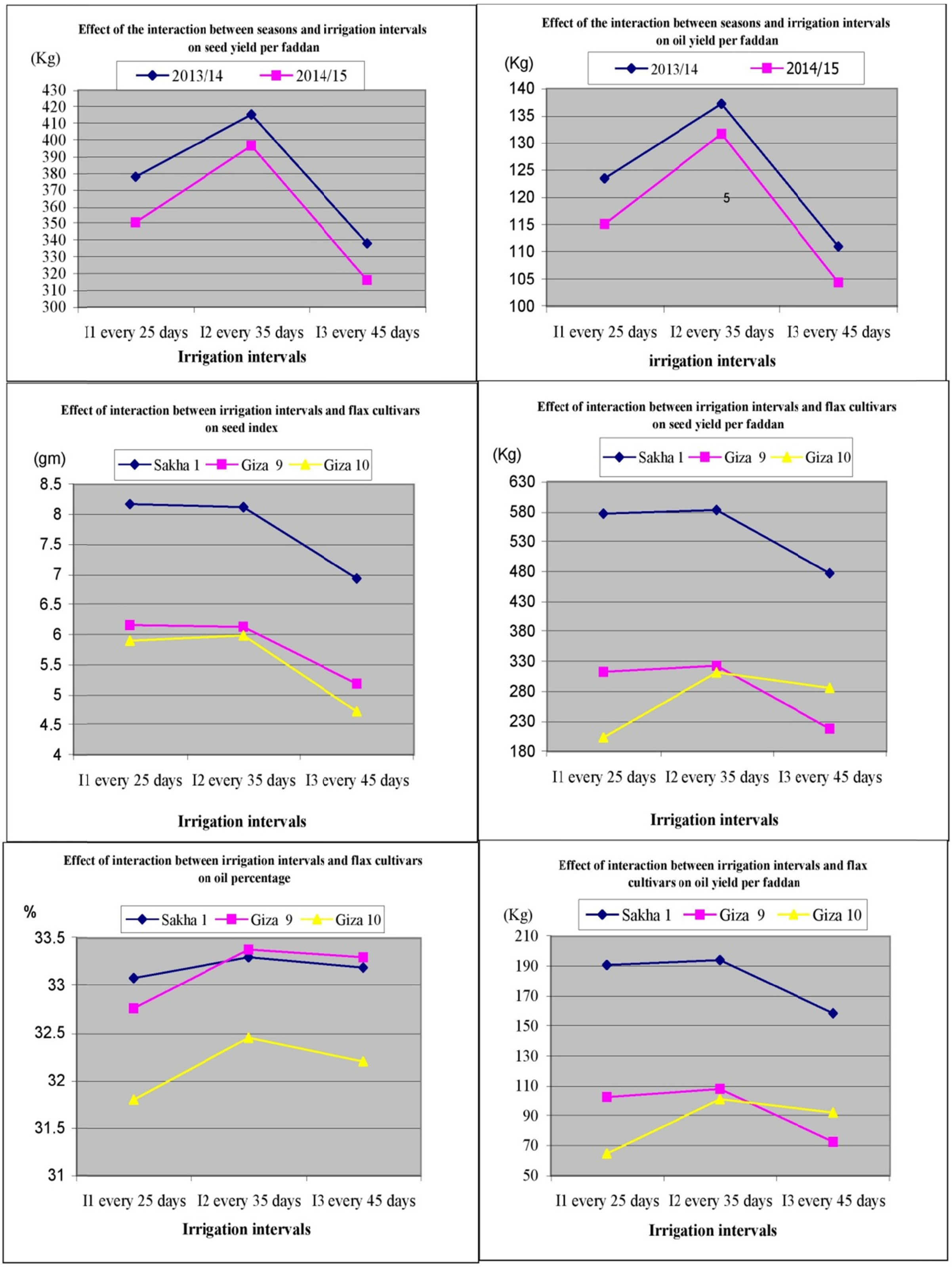

Figure 2. Effects of the first order interactions (seasons × irrigation intervals) and (irrigation intervals X flax cultivars) on seed yield and its traits

The effect of the second order interaction (seasons × irrigation intervals × flax cultivars) on seed yield per faddan was only significant (Table 6), while Sakha 1 cultivar recorded the highest value under both irrigation every 35 days and every 25 days in the first season.

Table 6. Interaction effects among seasons, irrigation intervals and flax cultivars on seed yield (per faddan trait)

Seasons	Irrigation intervals	Flax cultivars		
		Sakha 1	Giza 9	Giza 10
Seed yield per faddan (Kg)				
2013/14	I1 every 25 days	588.0	333.0	213.0
	I2 every 35 days	594.3	329.7	322.3
	I3 every 45 days	489.3	228.3	296.7
2014/15	I1 every 25 days	566.0	293.0	193.3
	I2 every 35 days	571.3	317.0	301.7
	I3 every 45 days	465.3	207.3	275.7
$LSD_{0.05}$		10.34		

3.3 Fiber Yield and Its Technological Characters

The analysis of variance for the combined data with regard to fiber fineness, fiber length, total fiber percentage and fiber yield per faddan showed highly significant differences among the three tested irrigation intervals (Table 7). Irrigation every 35 days gave the finest fiber, the tallest fiber length, the highest total fiber percentage and the highest fiber yield per faddan, followed by irrigation every 25 days which ranked the second. While the most coarseness fiber, shortest fiber length, lowest fiber yield per faddan and lowest total fiber percentage values were obtained by irrigation every 45 days (3 irrigation times).

Table 7. Means of fiber yield and its technological characters as affected by irrigation intervals (combined data)

Irrigation intervals	Fiber fineness (N.m)	Fiber length (cm)	Total fiber percentage (%)	Fiber yield per faddan (Kg)
I1 every 25 days	319.6	84.05	16.18	452.4
I2 every 35 days	329.2	87.36	17.04	515.6
I3 every 45 days	302.2	73.57	14.66	332.6
$LSD_{0.01}$	2.285	1.532	0.08664	9.345

The trend of these data was similar to the trend of straw yield and its related characters, which emphasize that, straw yield and plant height especially technical stem length (a long unbranched stem which contains the most high quality fiber) define the fiber biomass (Sankari, 2000). Similar trends were also stated by Elhaak et al. (1999) as a high percentage of valuable long fibers were a function of high soil moisture and fertility especially of N, P, K and Mg. Gabiana (2005) also mentioned that, the fiber yield per plant was three times more in irrigated plots than in rainfed plants. In other words, water stressed plants produced less fiber compared to irrigated plants with adequate water. Moreover, Bauer et al. (2015) reported that, irrigation increased fiber yield compared to rainfed plants.

The analysis of variance for the combined data showed highly significant differences among the three tested flax cultivars: Sakha 1, Giza 9 and Giza 10 (Table 8). Giza 10 cultivar gave the finest fiber, the tallest fiber length, the highest total fiber percentage and the highest fiber yield per faddan, followed by Giza 9, while the most coarseness fiber, the shortest fiber length, lowest fiber yield per faddan and lowest total fiber percentage values were obtained by Sakha 1. Such differences could be attributed to genetic constituents of cultivars, whereas, Giza 10 is a fiber type and Giza 9 and Sakha 1 are dual-purpose types. The fiber types gave the highest values of fiber percentage which were proportionally with the loss in straw yield per faddan after retting. The loss in straw yield per faddan after retting for dual-purpose (Giza 9 and Sakha 1) was higher than the other fiber type. These results are in agreement with these obtained by Abd El-Fatah (2007) and El-Refaey et al. (2010) and they reported that, fiber types exceeded dual and oil types in fiber fineness and it had superiority for fiber length character and recorded the highest fiber percentage and fiber yield per faddan. El-Azzouni and Zedan (2009) opined that, Giza 10 surpassed all other tested cultivars in fiber fineness. These results are in the same line with these obtained by Bauer et al. (2015) as they mentioned that, the higher fiber contents along with the higher straw yields resulted in the fiber-type cultivars yielding 60-70% more fiber than the seed-type cultivar.

Table 8. Means of fiber yield and its technological characters as affected by flax cultivars (combined data)

Cultivars	Fiber fineness (N.m)	Fiber length (Cm)	Total fiber percentage (%)	Fiber yield per faddan (Kg)
Sakha 1	280.4	78.97	10.95	359.2
Giza 9	322.9	81.93	17.99	444.2
Giza 10	347.6	84.08	18.94	497.3
L.S.D $_{0.01}$	2.132	1.208	0.08339	6.611

The effect of the first order interactions (seasons × irrigation intervals), (seasons × flax cultivars) and (irrigation intervals × flax cultivars) on fiber yield and its technological characters are presented in Figure 3. The interaction between seasons and irrigation intervals had highly significant effect on total fiber percentage, while it had only significant effect on fiber yield per faddan. Moreover, the interaction between seasons and flax cultivars had highly significant effect on total fiber percentage and fiber yield per faddan. In addition, the effect of the interaction between irrigation intervals and flax cultivars was highly significant on all fiber traits and Giza 10 cultivar recorded the highest values for all these traits under irrigation every 35 days.

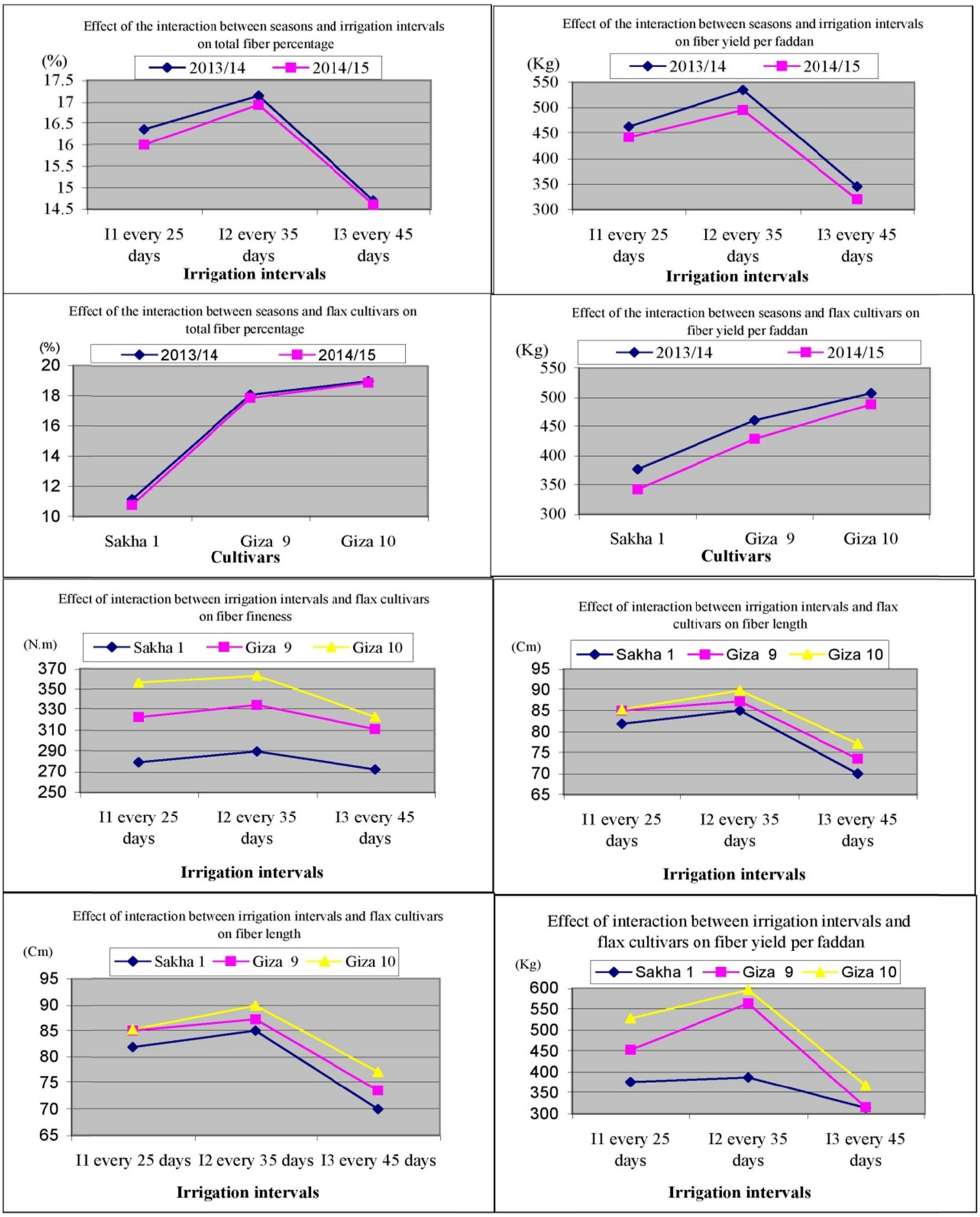

Figure 3. Effects of the first order interactions (seasons × irrigation intervals), (seasons × flax cultivars) and (irrigation intervals × flax cultivars) on fiber yield and its technological characters

The effect of the second order interaction (seasons × irrigation intervals × flax cultivars) on fiber fineness, total fiber percentage and fiber yield per faddan was highly significant and Giza 10 cultivar recorded the highest values for all these traits under irrigation every 35 days in the first season (Table 9).

These results clearly indicated that, the cultivars significantly differed in their responses to the irrigation intervals and the variability among tested flax cultivars which may be expected due to the differences of these cultivars in genetic constituent and the environmental conditions (Khalifa et al., 2011; El-Hariri et al., 2012).

Table 9. Interaction effects among seasons, irrigation intervals and flax cultivars on fiber yield and its technological characters

Seasons	Irrigation intervals	Flax cultivars		
		Sakha 1	Giza 9	Giza 10
Fiber fineness (N.m)				
2013/14	I1 every 25 days	280.5	324.9	357.9
	I2 every 35 days	292.5	332.2	363.9
	I3 every 45 days	273.5	312.5	320.6
2014/15	I1 every 25 days	278.1	320.9	355.1
	I2 every 35 days	286.8	337.4	362.6
	I3 every 45 days	271.1	309.8	325.4
$LSD_{0.01}$		5.222		
Total fiber percentage (%)				
2013/14	I1 every 25 days	11.39	18.21	19.50
	I2 every 35 days	11.64	19.69	20.10
	I3 every 45 days	10.36	16.38	17.36
2014/15	I1 every 25 days	10.84	17.73	19.44
	I2 every 35 days	11.23	19.52	20.04
	I3 every 45 days	10.22	16.39	17.23
$LSD_{0.01}$		0.2043		
Fiber yield per faddan (Kg)				
2013/14	I1 every 25 days	391.1	459.4	538.5
	I2 every 35 days	411.1	593.9	600.8
	I3 every 45 days	327.2	327.2	381.4
2014/15	I1 every 25 days	361.1	446.5	517.9
	I2 every 35 days	363.6	533.6	590.4
	I3 every 45 days	300.9	304.3	354.6
$LSD_{0.01}$		16.19		

4. Conclusion

From this study, it can be concluded that, irrigation intervals have a significant role on flax production and irrigation every 35 days (4 irrigation times during the growing season) performed the best traits. Among the cultivars, Giza 10 cultivar was superior in plant height, fiber fineness, fiber length, total fiber percentage and fiber yield per faddan traits. Meanwhile, Sakha 1 cultivar highly significantly surpassed other cultivars in main stem diameter, biological, straw yields per faddan, seed index, seed, oil yields per faddan and oil percentage.

References

Abd El-Fatah, A. A. E. (2007). Comparative study on some flax cultivars. *J. Agric. Sci. Mansoura Univ., 71*(9), 11-19.

Abd El-Fatah, A. A. E. (2007). Comparative study on some flax cultivars. *J. Agric. Sci. Mansoura Univ., 32*(9), 7111-7119.

Abd El-Wahed, M. H., El-Sabagh, A., Zayed, A., Sanussi, A., Saneoka, A., & Barutçular, C. (2015a). Improving yield and water productivity of maize grown under deficit-irrigated in dry area conditions. *Azarian Journal of Agriculture, 2*(5), 123-132.

Abd El-Wahed, M., El-Sabagh A., Saneoka, H., Abdelkhalek, A., & Barutçular, C. (2015b). Sprinkler irrigation uniformity and crop water productivity of barley in arid region. *Emirates J. of Food and Agriculture, 27*(10), 770-775.

Abo Zaied, T. A. (1997). *Comparative study of yield technological characters of some flax varieties* (PhD Thesis). Fac. of Agric. Mansoura Univ., Egypt.

Abou-Zaied, T. A., & Mousa, A. M. (2007). Effect of different NPK treatments on yield and yield components of two flax varieties. *J. Agric. Sci., Mansoura Univ., 32*(10), 8057-8064.

Aermae. (2007). *Agriculture Economic Report*. Ministry of Agriculture, Egypt.

Ahlawat, I. P. S., & Gangaiah, B. (2009). Effect of configuration and irrigation on sole and linseed (*Linum usitatissimum*) intercropped chickpea (*Cicre artietinum*). *Indian J. Agril. Sci., 80*(3), 250-253.

Ahmadizadeh, M. (2013). Physiological and Agro-Morphological Response to Drought Stress. *Middle-East J. Scientific Res., 13*(8), 998-1009.

Alessi, J., & Power, J. F. (1970). Influence of row spacing, irrigation, and weeds on dryland flax yield, quality, and water use. *Agron. J., 62*, 635-637. http://dx.doi.org/10.2134/agronj1970.00021962006200050026x

AOAC. (1990). *Official Methods of Analysis of the Association of Official Analytical Chemists* (15th ed.). Published by Association of Official Analytical Chemists, Arlington, Virginia, U.S.A.

Asgharipour, M., & Rafiei, M. (2010). Intercropping of Isabgol (*Plantago ovata* L.) and Lentil as Influenced by Drought Stress. *American-Eurasian Journal of Sustainable Agriculture, 4*(3), 341-348.

Assar, M. B. (2008). *Evaluation of some flax genotypes under different conditions* (M.Sc. thesis, p. 86). Fac. Agric., Tanta Univ., Egypt.

Bakry, A. B., Elewa, T. A., & Ali, O. A. M. (2012). Effect of Fe foliar application on yield and quality traits of some flax varieties grown under newly reclaimed sandy soil. *Australian J. Basic and Applied Sci., 6*(7), 532-536.

Barky, A. B., El-Hariri, D. M., Mervat Sh, S., & El-Bassiouny, H. M. S. (2012). Drought stress mitigation by foliar application of salicylic acid in two linseed varieties grown under newly reclaimed sandy soils. *Journal of Applied Sciences Research, 8*(7), 3503-3514.

Barky, A. B., Ibrahim, O. M., Elewa, T. A., & El-Karamany, M. F. (2014). Performance Assessment of Some Flax (*Linum usitatissimum* L.) Varieties Using Cluster Analysis under Sandy Soil Conditions. *Agricultural Sciences, 5*, 677-686. http://dx.doi.org/10.4236/as.2014.58071

Barutçular, C., Yıldırım, M., Koç M., Akıncı, C., Toptaş, I., Albayrak, O., ... El-Sabagh, A. (2016). Evaluation of SPAD chlorophyll in spring wheat genotypes under different environments. *Fresenius Environmental Bulletin, 25*(4), 1258-1266.

Bauer, P. J., & Frederick, J. R. (1997). Winter crop effect on double-cropped cotton grown with and without irrigation. In R. N. Gallaher & R. McSorley (Eds.), *Proc. of the 20th Ann. Southern Conservation Tillage Conf. for Sustainable Agric., June 24-26, 1997, University of Florida Special Series SS-AGR-60* (pp. 220-222).

Bauer, Ph. J., Stone, K. C., Foulk, J. A., & Dodd, R. B. (2015). Irrigation and cultivar effect on flax fiber and seed yield in the Southeast USA. *Industrial Crops and Products, 67*, 7-10. http://dx.doi.org/10.1016/j.indcrop.2014.12.053

Chavarria, G., & Dos Santos, H. P. (2012). Plant Water Relations: Absorption, Transport and Control Mechanisms, Advances in Selected Plant Physiology Aspects. In G. Montanaro (Ed.), *InTech*.

Chorumale, P. B., Dahatonde, B. N., & Vyas, J. S. (2001). Response of linseed to nitrogen under varied moisture regimes. *Ann. Plant Physiol., 13*(2), 192-194.

De Carvalho, G., De Sousa, B., Dos Santos, U. M., Fernandes, A. V., Barbosa, S., & Buckeridge, M. S. (2005). Growth, photosynthesis and stress indicators in young rosewood plants (*Aniba rosaeodora* Ducke) under different light intensities. *Braz. J. Plant Physiol., 17*, 325-334.

El-Azzouni, A. M. A., & Zedan, S. Z. (2009). Effect of sowing dates, foliar x as balanced compound fertilizer on yield and its components some flax varieties in sandy soil. *J. Agric. Sci., Mansora Univ., 20*(3), 2071-2084.

El-Azzouni, A. M. A., Moawed, E. A., & Salama, S. M. (2003). Effect of seeding rate, potassin fertilizer on some genotypes of flax (*Limun usitatissimum* L.). *J. Agric. Sci., Mansoura Univ., 28*(8), 5887-5902.

Elhaak, M. A., EI-Shourbagy, M. N., & EI-Nagar, R. (1999). Effect of edaphic factors on technical properties of flax fibre. *J. Agron. Crop Sci., 182*, 113-120. http://dx.doi.org/10.1046/j.1439-037x.1999.00273.x

El-Hariri, D. M., Barky, A. B., Elewa, T. A., & Ibrahim, O. M. (2012). Evaluation of some flax (*Linum usitatissimum* L.) varieties under newly reclaimed sandy soils conditions. *International Journal of Academic Research, 4*(1). 98-102.

El-Hariri, D. M., Hassanein, M. S., & El-Sweify, A. H. (2004). Evaluation of some flax genotypes, straw yield, yield components and technological characters. *J. of Natural Fibers, 1*(2), 697-715. http://dx.doi.org/10.1300/J395v01n02_01

El-Kady Eman, A. E., & Abd El-Fatah, A. A. E. (2009). Comparison of yield, its components physical properties and chemical composition of twelve flax genotypes. *J. Agric. Res. Kafr El-Sheikh Univ., 35*(1), 69-85.

EL-Kady, E. F. A., Shafshak, S. E., Gab-Allah, F. L., & Kineber, M. E. A. (1995). Effect of seeding rates on yield and its components for six promising flax genotypes under saline conditions. *J. Agric. Sci. Mansoura Univ., 20*(2), 593-602.

El-Refaey, R. A., El-Seidy, E. H., Abou-Zaied, T. A., & Ewes, A. A. (2009). *Breeding for the ideal plant type of fiber in flax through line × tester analysis* (pp. 69-84). The Fifth Inter. Conf. Sustain. Agric. Develop., Fac. Agric., Fayoum Univ.

El-Refaey, R. A., El-Seidy, E. H., Abou-Zaied, T. A., & Rashwan, E. A. (2010). *Evaluation of some genotypes of flax (Linum usitatissimum L.) for fiber and its related characters under different plant densities and retting methods* (pp. 165-187). The 12th Conference of Agronomy, Suez Canal Univ., Fac., Environ., Agric. Sci., September 20-22, 2010, El-Arish, Egypt.

El-Refaey, R. A., El-Seidy, E. H., Abou-Zaied, T. A., Abd El-Razek, U. A., & Rashwan, E. A. (2015). Effect of Different Mineral and Biological Nitrogenous Fertilizers Combinations on Straw Yield and Fiber Quality of Some Flax '*Linum usitatissimum* L.' Genotypes Glob. *J. Agric. Food Safety Sci., 2*(3), 346-364.

El-Sabagh, A., Barutçular, C., & Saneoka, H. (2015a). Assessment of drought tolerance maize hybrids at grain growth stage in mediterranean area. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering, 9*(9), 962-965.

El-Sabagh, A., Omar, A., Barutçular, C., & Saneoka, H. (2016b). Role of integrated use of nitrogen fertilizer sources in improving seed quality of canola (*Brassica napus* L.). *Turkish Journal of Agriculture - Food Science and Technology, 4*(2), 73-78.

El-Sabagh, A., Sorour, S., Morsi, A., Islam, M. S., Ueda, A., Barutcular, C., … Saneoka, H. (2016a). Role of Osmoprotectants and compost application in improving water stress tolerance in soybean (*Glycine max* L.). *International Journal of Current Research, 8*(2), 25949-25954.

El-Sabagh, A., Sorour, S., Omar, A., Islam, M. S., Ueda, A., Saneoka, H., & Barutçular, C. (2015b). *Soybean (Glycine max L.) Growth Enhancement under Water Stress Conditions* (pp. 148-152). International Conference on Chemical, Agricultural and Biological Sciences, (CABS-2015), Sept. 4-5, 2015, Istanbul, Turkey.

El-Seidy, E. H., El-Refaey, R. A., Abou-Zaied, T. A., & Rashwan, E. A. (2010). *Evaluation of some flax genotypes for seed yield and its related characters under different plant densities* (pp. 691-703). The 12th Conference of Agronomy, Suez Canal Univ., Fac. Environ. Agric. Sci., September 20-22, 2010, El-Arish, Egypt.

El-Seidy, E. H., El-Refaey, R. A., Abou-Zaied, T. A., Abd El-Razek, U. A., & Rashwan, E. A. (2015). Effect of Different Mineral and Biological Nitrogenous Fertilizers Combinations on Seed Yield and its components of Some Flax '*Linum usitatissimum* L.' Genotypes. *Glob. J. Agric. Food Safety Sci., 2*(3), 365-383.

El-Shahaway, T. A., Rookiek, K. G., Balbaa, L. K., & Abbes, S. M. (2008). Micronutrients, B-vitamins and yeast in relation to increasing flax (*Linum usitatissimun* L.). Growth, yield productivity and controlling associated weeds. *Asian Journal of Agricultural Research, 2*, 1-14. http://dx.doi.org/10.3923/ajar.2008.1.14

El-Sweify Amna, H. H., Abd El-Daim, M. A., & Hussein, M. M. M. (2006). Response of some flax genotypes to pulling date under newly reclaimed sandy soil and sprinkler irrigation conditions. *Egypt. J. Agric. Res., 84*(4), 1103-1115.

Gabiana, C. P. (2005). *Response of linseed (Linum usitatissimum L.) to irrigation, nitrogen and plant population* (M.Sc. thesis, p. 85). Lincoln Univ., New Zealand.

Genser, A. D., & Morris, N. D. (2003). History of cultivation and uses of flaxseed. In A. D. Muir & N. D. Westcott (Eds.), *Flax - The genus Linum*. Taylor and Francis. London.

Islam, M. S., Akhter, M. M., El-Sabagh, A., Liu, L. Y., Nguyen, N. T., Ueda, A., et al. (2011). Comparative studies on growth and physiological responses to saline and alkaline stresses of Foxtail millet (*Setaria italica* L.) and Proso millet (*Panicum miliaceum* L.). *Aust. J. Crop Sci., 5*, 1269-1277.

Khalifa, R. Kh. M., Manal, F. M., Bakry, A. B., & Zeidan, M. S. (2011). Response of some flax varieties to micronutrients foliar application under newly reclaimed sandy soil. *Australian Journal of Basic and Applied Sciences, 5*(8), 1328-1334.

Kinebar, M. E. A. (2004). Effect of environmental conditions on yield and its quality of two flax cultivars. *J. Agric. Sci., Mansoura Univ., 44*(8), 1-12.

Kineber, M. E. A., El-Emary, F. A., & El-Nady, M. F. (2006). Botanical studies on some fibrous flax (*Linum usitatissmum* L.) genotypes grown under Delta conditions. *J. Agric. Sci., Mansoura Univ., 31*(5), 2881-2890.

Le Clerg, E. L., Leonard, W. H., & Clerk, A. G. (1962). *Field plot technique* (p. 300). Burgess Publication Company, Minneapolis, Minnesota.

Lisson, S. N., & Mendham, J. J. (2000). Agronomic studies of flax (*Linum usitatissimum* L.) in south-eastern *Australia. Aust. J. Exp. Agric., 40*, 1101-1112. http://dx.doi.org/10.1071/EA00059

Mirshekari, M., Amiri, R., Nezhad, H., Noori, S. A. S., & Zandvakili, O. R. (2012). Effects of planting date and water deficit on quantitative and qualitative traits of flax seed. *American-Eurasian J. Agric. Environ. Sci., 12*(7), 901-913.

Pandey, R., & Agarwal, R. M. (1998). Water stressinduced changes in praline contents and nitrate reductase activity in rice under light and dark conditions. *Physiol. Mole. Biol. Plants, 4*, 53-57.

Radwan, S. R. H., & Momtaz, A. (1966). The technological properties of flax fibers and the methods of estimating them. *El-Falaha J., 46*(5), 466-476.

Sankari, H. S. (2000). Linseed (*Linum usitatissimum* L.) cultivars and breeding lines as stem biomass producers. *Journal of Agronomy and Crop Science, 184*, 225-231. http://dx.doi.org/10.1046/j.1439-037x.2000.00375.x

Sharma, G., Sutalya, R., Prasad, S., & Sharma, I. (2012). Effect of irrigation and intercropping system on growth, yield and quality of mustered and linseed. *Crop Res. Hisar., 25*(3), 579-581.

Snedecor, G. W., & Cochran, W. G. (1982). *Statistical Methods* (6th ed.). Iowa State Univ. Press, Ames., Iowa, USA.

Szilgyi, L. (2003). Influence of drought on seed yield components in common bean. *Bulg. J. Plant Physiol., Special Issue*, 320-330.

Taiz, L., & Zeiger, E. (2006). *Plant Physiology* (5th ed., p. 20). Sinauer Associates Inc., Publishers Sunderland, Massachusetts, U.S.A.

Wood, I. M. (1997). *Fibre Crops - New opportunities for Australian agriculture* (pp. 18-24). Department of Primary Industries, Brisbane.

Yenpreddiwar, M. D., Nikam, R. R., Thakre, N. G., Harsha, K., & Sharma, S. K. (2007). Effect of irrigation and moisture conservation practices on yield of linseed. *J. Soils Crops, 17*(1), 121-127.

Zahana, A. E. A., Abo-Kaied, H. M. H., & Ashry, N. A. (2003). Effect of different zinc levels and Mycorrhiza fungi and their combinations on flax. *J. Agric. Sci. Mansoura Univ., 28*(1), 67-76.