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EFFECT OF IRRIGATION INTERVALS AND NITROGEN FERTILIZER RATES ON FLAX YIELD AND SOME ANATOMICAL MANIFESTATIONS

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ABESTRACT: *Two field experiments were carried out at Gemmeiza Research Station, El-Gharbia Governorate, Agricultural Research Center, Egypt, during the two successive winter seasons of 2015/2016 and 2016/2017. The objective of this work was to evaluate the effect of irrigation intervals (every 21, 28 and 35 days) and nitrogen fertilizers rates [untreated (0), 30, 45 and 60 kg N/fad] on quantity and quality of straw and seed characters of flax (Cultivar Giza 10), in addition to study anatomical manifestation in middle technical stem length. The experimental design was split-plot in three replications.*

Significant differences were detected for all studied traits, i.e. total plant height (cm), technical stem length (cm), upper branching zone length (cm), straw yield/plant (g), straw yield (kg/fad), total fiber percentage (%), fiber yield (kg/fad), fiber length (cm), number of capsules/plant, number of seeds/capsule, seed index (g),seed yield/plant (g), seed yield (kg/fad), biological yield (kg/fad), oil percentage (%) oil yield (kg/fad)and fiber fineness (Nm) among irrigation intervals or nitrogen fertilizer rates in the combined analysis.

Irrigated flax plants every 21 days gave the maximum values for total plant height (cm), technical stem length (cm), upper branching zone length (cm), straw yield/plant (g), straw yield (kg/fad), total fiber percentage (%), fiber yield (kg/fad), fiber length (cm), number of capsules/plant, number of seeds/capsule, seed index (g), seed yield/plant (g), seed yield (kg/fad), biological yield (kg/fad), oil percentage (%) and oil yield (kg/fad) in the combined analysis. On the other hand, significantly gave the low values of fiber fineness (Nm). In contrast, irrigation every 35 days gave the minimum values for all studied characters under this study except, fiber fineness (Nm). Irrigated flax every 28 days gain intermediate estimates in all studied traits without significance with irrigation every 21days. Anatomical studies, i.e. total cross section area (mm^2), cortex area (mm^2), fiber area (mm^2), xylem area (mm^2) and pith area (mm^2), fiber index (cm^3), cortex % and fiber % were increased when irrigated flax plants every 21 days. But xylem % and pith % were decreased.

All traits of flax under study showed significantly increased by increasing nitrogen fertilizer rates from untreated up to 60 kg N/fad, except fiber fineness (Nm) was significant decreased with increasing nitrogen rates in the combined analysis. Results reported that no significant differences between soil fertilized by 45 and 60 kg N/fad on all flax traits under study. All anatomical studies, i.e., (total cross section area (mm^2), cortex area (mm^2), fiber area (mm^2), xylem (mm^2), pith (mm^2), fiber index (mm^3), cortex %, fiber % and xylem %) were increased with increasing nitrogen fertilizer rates up to 60 kg N/fad, expect pith % was decreased.

Results showed that irrigated flax plants every 21 days and soil fertilized by 60 kg N/fad significantly gave the maximum values of seed, biological and oil yield (kg/fad) in the combined analysis. In addition to great reduction in fiber fineness (Nm) had happened in this case.

It could be concluded that planting flax plants (Giza 10) under irrigated interval every 21 or 28 days and soil fertilized by 45 or 60 kg N/fad to maximized quantity and quality of straw and seed yield characters as well as anatomical studies.

Key words: *Flax, water intervals, nitrogen fertilizer rates, growth, production, quality and anatomical manifestation.*

INTRODUCTION

Flax is now unknown in the wild but originally it may have been a native of Asia. It has been cultivated since at least 5000 BC, probably first by the ancient Mesopotamians and later by the Egyptians who wrapped their mummies in linen cloth. The seeds are widely used medicinally. Their constituents include 30-40% of fatty oil (linseed oil) with esters of linoleic acid, linolenic acid, stearic acid and oleic acid; also mucilage, proteins, a cyanogenic glycoside (linamarin) and enzymes. Whole of crushed, the seeds are a reliable means of relieving constipation. Externally, crushed seeds mixed to a paste with water are used to make hot poultices to relieve pain and to heal septic wounds, skin rashes and ulcers. The extracted oil is used in the pharmaceutical industry to make liniments for burns and rheumatic pain. The poiled oil is also important in the manufacture of paints, soap and printer's ink. In Egypt, flax (*Linum usitatissimum*, L.) is cultivated as a dual purpose (seeds for oil and stems for fiber). The growing area of flax in Egypt during 2015/2016 year is about 14541 fed with a total straw yield of 65434.5 ton and total seed yield of 6179.9 ton (Bull. Agric. Stat., 2016). The cultivated area through the last 20 years was decreased from 60.000 to 30.000 fad due to the great competition of other economic winter crops resulting in a gap between production and consumption. Therefore, it is necessary to increase flax productivity per unit area which could be achieved by using high yielding varieties and improving different agriculture treatments to gain highest yield characterize by best quality.

Water is well known essential constituent of living organism for their growth and development. Excess or deficit use of water, reduces the crop yield drastically. Water stress during the active crop growth phase results into suppression of crop growth as it influences the photosynthesis and other physiochemical processes and or death, by desiccation. The excess water leads in to the problems of raising water table, soil salinity. Hence, water management studies have become an important aspect of research for irrigated crops. Irrigation is mainly given to crop for achieving maximum yield with better quality of produce. The intervals of irrigation in flax plays an important role in the growth and development of linseed crop by supplementary irrigation at critical growth stages, particularly sensitive to water stress which ultimately highly positive effect on crop growth and seed yield. Due to proper water use, flax straw and seed yield were significantly affected by intervals of irrigation. Husain *et al.,* (2009), Mirshekari *et al.,* (2012), Sharma *et al*., (2012), Hassan and Shaler (2013), Padamchand (2015), Patel (2016) and Rashwan *et al*., (2016) showed that irrigation intervals significantly influenced all studied traits of flax. Kayembe (2015) revealed that irrigated kenaf plants significantly increased all anatomical manifestations {total cross section area (mm^2), cortex area (mm^2), fiber area (mm^2), xylem area (mm^2) and pith area (mm^2), fiber index (cm^3), cortex % and fiber %}, expect xylem % and pith % were decreased as compared to rainfed kenaf plants.

Nitrogen is the major nutrient required by plants for their better growth and development. Nitrogen is an essential element for flax growth to build up protoplasm and protein which induce cell division, meristematic activity and further

increased cell number and size with an overall increase in flax growth, consequently more fiber and seed production. Different reports by different researchers revealed that seed and straw yield as well as components of flax varied with site and year without showing a constant trend and some studies points to a limited response to nitrogen application when soil nitrate rates are high. Therefore, the response of flax to nitrogen application is affected by the rates of soil available nutrient, soil type, and climate and moisture conditions during the growing season, nitrogen fertilizer form and placement. Several investigations reported that increasing nitrogen fertilizer rates caused significant increase in all straw and seed characters of flax, expect, fiber fineness was significantly decreased El-Shimy *et al.,* (1993), Mostafa *et al*., (2003), Husain *et al.,* (2009), El-Nagdy *et al*., (2010), Fataneh *et al*., (2012), Sharma *et al*., (2012), Upadhyay *et al.,* (2012), Hassan and Shaler (2013) Homayouni *et al*., (2013), Singh *et al*., (2013), Soethe *et al*., (2013), Kariuki *et al*., (2014), Kumar *et al*., (2014), Lilian *et al*., (2014), Andruszczak *et al*., (2015), Gudeta (2015), Padamchand (2015) and Patel (2016). Concerning anatomical studies, El-Shimy *et al*., (1993), Mostafa *et al*., (2003) and El-Nagdy *et al*., (2010) showed that gradual and significant increments for all anatomical characters due to increasing nitrogen rate except pith area which decreased significantly with increasing nitrogen rate.

The main target of this investigation is to determine the suitable irrigation interval and optimum nitrogen fertilizer rate, which achieve highest yield production from flax fiber and seeds, in addition to their quality as well as anatomical manifestations in farm of El-Gemmeiza Research Station, El-Gharbia Governorate.

MATERIALS AND METHODS

Two field experiments were carried out at the Farm of Gemmeiza Research Station, El-Gharbia Governorate, Agricultural Research Center, Egypt, during the two successive winter seasons of 2015/2016 and 2016/2017. The aim of this study was to investigate the effect of irrigation intervals and nitrogen fertilizer rates on quantity and quality of straw and seed characters of flax (Cultivar Giza 10) as well as anatomical manifestations in middle part of technical stem length. Soil texture of the experimental site was clay-loam of pH nearly of 7.8. The chemical and mechanical properties of the experimental soil were determined according to the standard procedures described by Black and Evans (1965) and represented in Table 1 in each of the two growing seasons.

Each experiment included 12 treatments, which were the combination of three irrigation intervals and four nitrogen fertilizer rates.

Factors under study were as follows:

1. Irrigation intervals:

- Flax irrigated every 21, 28 and 35 days.

For the establishment of the crop, first common irrigation was giving after 21 days after sowing. Subsequent irrigations were given as per schedule given in Table 2.

2. Nitrogen fertilizer rates:

- Untreated (control)
- 30 kg N/fad.
- 45 kg N/fad.
- 60 kg N/fad.

Nitrogen fertilizer was applied in form of urea (46.5 % N), and divided into two equal parts and applied before the first and second irrigations in each season.

Seeds of flax *cv.* Giza 10 (a fiber type) which produced by Fiber Crops Research Section, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. The experimental design was split-plot in three replications. The three irrigation

intervals treatments were distributed in the main plots, whereas the four nitrogen fertilizer rates were arranged at random in sub-plots. The preceding summer crop in the two seasons was rice crop. The sub-plot area was 21 m^2 (4 X 5.25 m). Experiments were planted on November 1th and 7th in the first season 2015/2016 and the second season 2016/2017, respectively. Seeds were broadcasting at the rate of 60 kg seeds / fad. Phosphorous fertilizer was applied in form of Calcium super phosphate (12.5 % P_2O_5) at a rate of 100 kg/fad during soil preparation in each season. The other recommended agronomic practices of growing flax were applied in the manner prevailing in the region were practiced.

Data recorded:

At maturity, about 150 days from sowing date, ten guarded plants were taken randomly from each sub-plot for recording the straw and seed /plant traits. Straw yield/fad, seed yield/fad and biological yield/fad were estimated according to yield from four meter square of each sub-plot. After harvesting and removing the capsules from plants from one meter square of each sub-plot, retting process took place at Fiber Crops Research Section, Gemmeiza Agriculture Research Station. Straw of each sub-plot was arranged in bundles and put in retting basins and soaked in water for about 12 hours. After soaking, the water was changed to leach out all the soluble materials. Retting interval was about one week in summer season. The degree of water temperature during retting process ranged from 28 to 32^{o}C and the acidity was pH 6-7. The retted straw was washed with water and finally dried in open air. Thus, the fibers were easily extracted from above the woody part of the stem.

Table 1: Chemical and mechanical properties analysis of the experimental soil units of the two growing seasons 2015/2016 and 2016/2017 seasons.

Properties analysis	Season	
	2015/2016	2016/2017
Chemical analysis		
E.C. (ds/m) in (1:5) soil water extract.	3.42	3.40
pH (1 :2.5)	7.9	7.7
$CaCo_3$ %	1.9	2.1
O.M %	1.92	1.98
N % (total)	0.10	0.12
N (ppm) (available)	27.08	31.93
Particle size distribution (mechanical analysis)		
Course sand %	9.2	8.1
Find sand %	18.4	19.2
Silt %	28.1	26.5
Clay %	44.3	46.2
Texture grade	Clay-Loam	Clay-Loam

Table 2: Date and number of irrigations during flax growth at 2015/2016 and 2016/2017 seasons.

Treatment	irrigation number								No. of irrigations applied
	Planting irrigation	First irrigation	Second irrigation	Third irrigation	Fourth irrigation	Fifth irrigation	Sixth irrigation	Harvest date	
The first season (2015/2016)									
Every 21 days	1/11/2015	22/11/2015	14/12/2015	3/1/2016	24/1/2016	14/2/2016	6/3/2016	30/3/2016	6
Every 28 days	1/11/2015	22/11/2015	20/12/2015	17/1/2016	14/2/2016	13/3/2016	--	30/3/2016	5
Every 35 days	1/11/2015	22/11/2015	27/12/2015	31/1/2016	6/3/2016	--	--	30/3/2016	4
The second season (2016/2017)									
Every 21 days	7/11/2016	28/11/2016	19/12/2016	9/1/2017	30/1/2017	20/2/2017	13/3/2017	6/4/2017	6
Every 28 days	7/11/2016	28/11/2016	26/12/2016	23/1/2017	20/1/2017	20/3/2017	--	6/4/2017	5
Every 35 days	7/11/2016	28/11/2016	2/1/2017	6/2/2017	13/3/2017	--	--	6/4/2017	4

Characters studied:

A- Straw yield and related characters:

1. Total Plant height (cm). It was measured from the cotyledonary node till the top of the plant.
2. Technical length of the main stem (cm). It was measured from the cotyledonary node till the beginning of apical branching zone of the main stem.
3. Upper branching zone length (cm). It was measured from the beginning of apical branching zone of the main stem till the top of the plant.
4. Straw yield/plant (g). It was estimated according to weight of air dried straw yield/plant.
5. Straw yield (kg/fad). It was estimated according to weight of air dried straw yield/4 m^2 from each subplot. The seed yield was subtracted from biological yield to obtain straw yield.
6. Total fiber %. It was calculated from the following formula:

$$\text{Total fiber \%} = \frac{\text{Fiber yield/m}^2}{\text{Straw yield/m}^2} x100.$$

7. Fiber yield (kg/fad). It was estimated according to fiber yield/1 m^2 of each sub-plot.

$$\text{Fiber yield(kg/fad)} = \frac{\text{Straw yield (Kg/fad) x Total fiber \%}}{100}.$$

8. Fiber length (cm). It was calculated from ten fiber ribbons from each treatment were spreaded out and each ribbon was measured then the average fiber length was recorded.
9. Fiber fineness (Nm). It was determined using Radwan and Momtaz (1966) methods according to the following equation:

$$\text{Nm} = \frac{\text{N x L}}{\text{W}}.$$

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

B- Seed yield and related characters:

10. Number of capsules/plant.
11. Number of seeds/capsule.
12. Seed index (g).
13. Seed yield/plant (g).
14. Seed yield (kg/fad). The total biomass harvested from 4 m^2 from all sub-plot was threshed, cleaned and dried. Seeds thus obtained were weighed and then converted into seed yield (kg/fad).
15. Biological yield (kg/fad). The thoroughly dried total harvested produce of 4 m^2 from all sub-plot was weighed and expressed as biological yield (kg/fad).
16. Oil %. It was determined as described by the (A.O.A.C., 1990) methods, using petroleum ether (40-60 °C) in Soxhlet apparatus.
17. Oil yield (kg/fad). It was calculated by multiplying seed yield (kg/fad) X oil %.

C- Anatomical Studies:

In the second season (2016/2017), at maturity stage , while plants were standing in the field , samples of five plants from each treatment were chosen from the main stems and the longest branches at middle region always taken at the same level 30 cm from soil surface from irrigation intervals treatments under soil fertilized by 60 kg N/fad, whereas, from nitrogen fertilizer levels under flax irrigated every 21 days. These samples were killed and fixed for 36 hours in F.A.A. "Formalin, Acetic acid and Alcohol Ethyle as –follow: "200 ccs. of 50% alcohol, 13ccs. Formalin, 50 ccs, Acetic acid. This solution (F.A.A.) can be used as Killing, fixing, and for preservation for some time. After fixation, samples were washed in distilled water , then dehydrated in the following steps ; 15% , 30% , 45% , 60% , 70% , 80% , 96% and 100% of alcohol. Samples were kept in each solution for five hours, xylol as a clearing agent rendered the specimen transparent. It replaced the dehydrating agent with a solvent of paraffin. The specimens were passed through

a series of gradual increasing strength of "xylol", and absolute alcohol, for each grade five hours. Embedding was done in paraffin wax of 52 ^{0}c. melting point. Samples were microtomed at 25 microns on a sliding microtome. The slides were smeared with small quantity of Mayer Albumen before mounting the ribbon. Sections were stained in 0.5% safranin solution which stained the nucleus and Lignified tissues with red tan. Tissues were counter stained with 1% light green dissolved in clove oil which gave the cytoplasm and cell wall a green color. Measurements of the total cross section, cortex, fiber, xylem and pith tissues were done by Visopan apparotus, drawings at magnification of 50x. The above tissues were measured by means of planimeter, and then calculated to its absolute amount to the nearest mm, using Sass (1951) method for cutting and Johanson (1940) for pigmenting method.

Anatomical characters:

C_1-Tissues area:

- Total cross section area (mm^2).
- Cortex area (mm^2).
- Fiber area (mm^2).
- Xylem area (mm^2).
- Pith area (mm^2).
- Fiber index (mm^3):

Fiber area (mm^2) per the corresponding Total cross section area (mm^2) X Technical stem length.

C_2-Percentage of different tissues per cross section:

- $$\text{Cortes } \% = \frac{\text{Cortex area } (mm^2)}{\text{Total cross section } (mm^2)} x\ 100.$$
- $$\text{Fiber } \% = \frac{\text{Fiber area } (mm^2)}{\text{Total cross section } (mm^2)} x\ 100.$$
- $$\text{Xylem } \% = \frac{\text{Xylem area } (mm^2)}{\text{Total cross section } (mm^2)} x\ 100.$$
- $$\text{Pith } \% = \frac{\text{Pith area } (mm^2)}{\text{Total cross section } (mm^2)} x\ 100.$$

Statistical analysis:

The analysis of variance was carried out according to the procedure described by Gomez and Gomez (1984). Data were statistically analyzed for each season and the homogeneity of experimental error, in both seasons, was tested. Then, the combined analysis of the two seasons was done according to using the MSTAT-C Statistical Software Package (Michigan State University, 1983). Where, the F-test showed significant differences among means LSD test at 0.05 level was used to compare between treatments means.

RESULTS AND DISCUSSION

A- Straw yield and related characters:

Mean values of straw characters for flax as affected by irrigation intervals and nitrogen fertilizer rates in 2015/2016, 2016/2017 and combined analysis are presented in Table 3.

Data obtained revealed that all nine straw traits significantly differed in the combined analysis over both seasons concerning the two studied factors *i.e.*, irrigation intervals and nitrogen rates. Regarding irrigation intervals effect in the combined results, irrigated flax plants at the shortest intervals (21 days) achieved maximum estimates in total plant height, technical stem length, upper branching zone length, straw yield/plant, straw yield/fad, total fiber percentage, fiber yield/fad and fiber length. In the same time, fiber fineness character was in the opposite direction. By means that more amount of water which added to plants at the shortest interval caused more coarse fiber and decrease fiber fineness (Nm) in comparison with the longest irrigation one. This behavior may be due to deposit more cellulosic layers on the primary wall inside to make secondary cell wall as resulting to more solvent nutrients from the soil. Many investigators came out with similar results as Husain *et al.,* (2009), Mirshekari *et al.,* (2012), Sharma *et al*., (2012), Hassan and Shaler (2013), Padamchand (2015), Patel

(2016) and Rashwan *et al*., (2016). The differences between irrigation at 21 days and 28 days did not reach the rate of significance in all straw characters. The results obtained from the combined over both seasons, the superiority ratios between irrigation at 21 days and either 28 or 35 days were 3.63 and 15.12 % for total plant height; 3.54 and 15.60 % for technical length; 3.69 and 11.97 % for upper branching zone length; 2.50 and 11.37 % for straw yield/plant; 5.99 and 23.58 % for straw yield kg/fad; 2.34 and 7.67 % for total fiber percentage; 8.45 and 32.81 % for fiber yield/fad in addition to 3.78 and 18.27 % for fiber length. Meanwhile, the superiority percentage between fiber fineness estimates which irrigated every 35 days and each of 28 and 21 days were 6.73 and 10.73%, respectively.

Table (3): Mean values of straw yield and its related traits for the flax as affected by irrigation intervals and nitrogen fertilizer rates (combined analysis over 2015/2016 and 2016/2017 seasons).

Treatment		Total plant height (cm)	Technical stem length (cm)	Upper branching zone length (cm)	Straw yield/ plant (g)	Straw yield/ fad (kg)	Total fiber %	Fiber yield/fad (kg)	Fiber length (cm)	Fiber fineness (Nm)
Irrigation interval										
21 days		125.6	108.2	17.40	3.193	4813.9	19.24	930.2	104.2	173.4
28 days		121.2	104.5	16.78	3.115	4541.8	18.80	857.7	100.4	179.9
35 days		109.1	93.6	15.54	2.867	3895.3	17.87	700.4	88.1	192.0
LSD at 5%		6.1	4.8	1.42	0.305	342.0	0.71	86.1	5.9	5.3
Nitrogen fertilizer rate										
Untreated		107.5	94.3	13.17	2.574	3699.8	17.17	637.9	89.2	189.6
30 kg N/fad		117.9	101.1	16.83	3.057	4389.8	18.54	815.6	97.1	184.3
45 kg N/fad		123.3	105.4	17.83	3.200	4695.0	19.27	906.8	101.2	178.4
60 kg N/fad		125.9	107.5	18.45	3.401	4883.2	19.56	957.4	102.8	174.9
LSD at 5%		4.2	3.0	1.24	0.243	263.0	0.51	69.6	3.7	4.0
The interaction effect between irrigation interval and nitrogen fertilizer rate										
21 days	Untreated	116.1	101.9	14.25	2.730	4095.0	17.86	731.2	97.1	180.8
	30	125.2	107.3	17.90	3.189	4783.5	19.03	910.1	104.0	177.2
	45	129.4	110.9	18.45	3.327	5090.0	19.92	1013.9	107.0	169.3
	60	131.8	112.8	19.00	3.525	5287.0	20.16	1065.6	108.6	166.4
28 days	Untreated	111.2	97.9	13.35	2.652	3845.5	17.36	667.5	94.0	186.2
	30	120.2	103.0	17.20	3.099	4493.5	18.72	841.3	99.4	183.4
	45	125.7	107.7	18.00	3.254	4818.0	19.38	933.4	103.5	177.0
	60	127.9	109.3	18.55	3.455	5010.0	19.74	988.8	104.7	172.9
35 days	Untreated	95.2	83.3	11.90	2.340	3159.0	16.30	514.9	76.6	201.6
	30	108.4	93.0	15.40	2.884	3892.5	17.87	695.5	87.8	192.4
	45	114.8	97.7	17.05	3.020	4177.0	18.51	773.2	93.0	189.0
	60	118.2	100.4	17.80	3.224	4352.5	18.79	817.8	95.1	185.3
LSD at 5%		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	7.0

Results indicated that increasing nitrogen fertilizer rates from the untreated (0) up to 60 kg N/fad caused remarkable increments in the eight straw characters *i.e.*, total plant height, technical stem length, upper branching zone length, straw yield/plant, straw yield/fad, total fiber percentage, fiber yield/fad and fiber length.in the combined over both seasons. The superiority rations in the combined analysis between the highest nitrogen rate (60 kg N/fad) and each of 45, 30 and 0 kg N/fad were 2.11, 6.79 and 17.12 % for total plant height; 1.99, 6.33 and 14.00 % for technical length; 3.48, 9.63 and 40.09 % for upper branching zone length; 6.28, 11.25 and 32.13 % for straw yield/plant; 4.01, 11.24 and 31.99 % for straw yield kg/fad; 1.50, 5.50 and 13.92 % for total fiber percentage; 5.58, 17.39 and 50.09 % for fiber yield/fad in addition to 1.58, 5.87 and 15.25 % for fiber length, respectively. Meanwhile, increase nitrogen rate caused more coarse fiber, by means that more fine fiber obtained from the untreated. The estimates of fiber fineness from the combined were 189.6 Nm for the untreated, 184.3 Nm for added 30 kg N/fad, 178.4 Nm from the nitrogen rate 45 kg/fad and 174.9 Nm for applying 60 kg N/fad. The superiority ratios between the untreated and each of added 30, 45 and 60 kg N/fad were 2.88, 6.28 and 8.40 %, respectively. Similar results were also obtained by El-Shimy *et al.,* (1993), Mostafa *et al*., (2003), Husain *et al.,* (2009), El-Nagdy *et al*., (2010), Fataneh *et al*., (2012), Sharma *et al*., (2012), Upadhyay *et al.,* (2012), Hassan and Shaler (2013) Homayouni *et al*., (2013), Singh *et al*., (2013), Soethe *et al*., (2013), Kariuki *et al*., (2014), Kumar *et al*., (2014), Lilian *et al*., (2014), Andruszczak *et al*., (2015), Gudeta (2015), Padamchand (2015) and Patel (2016).

The interaction effect between irrigation intervals and nitrogen fertilizer rates had significant effect on fiber fineness in the combined analysis. The maximum fiber fineness (201.6 Nm) was achieved by irrigated flax plants every 35 days without nitrogen fertilizer was added. On the other hand, irrigated flax plants every 21 days with soil fertilized by the 60 kg N/fad gave the minimum fiber fineness (166.4 Nm). Similar results were also obtained by Husain *et al*., (2009).

B- Seed yield and related characters:

From Table 4, results showed significant differences between each of either irrigation intervals or nitrogen fertilizer rates in biological yield/fad (kg) and seed characters *i.e.,* number of capsules/plant, number of seeds/ capsule, seed index, seed yield/plant, seed yield/fad, oil seed content % and oil yield in the combined analysis.

Irrigated flax plants every 21 days achieved an increment in biological yield/fad and all seed characters under study. The superiority ratios between irrigation at 21 days and each of 28 and 35 days in the combined analysis were 8.99 and 28.23 % for No. of capsules/plant; 3.23, 12.47 % for No. of seeds/capsule; 3.74 and 11.81 for seed index; 16.33 and 61.32 % for seed yield/plant; 16.31 and 61.05 % for seed yield/fad; 6.87 and 26.30 for biological yield/fad; 3.42 and 10.31 for oil seed percentage in addition to 20.08 and 77.30 % for oil yield/fad. Similar results were also obtained by Husain *et al.,* (2009), Mirshekari *et al.,* (2012), Sharma *et al*., (2012), Hassan and Shaler (2013), Padamchand (2015), Patel (2016) and Rashwan *et al*., (2016).

In relation to nitrogen fertilizer rates effect, the seed traits illustrated clear increments in these characters with increasing nitrogen rate up to 60 kg/fad without significance with applying 45 kg N/fad in the combined analysis. The superiority percentages between added the highest dose (60 kg N/fad) and each of 45, 30 kg N/fad and untreated in combined analysis over both seasons were 4.55, 11.33 and 40.76 % for No. of capsules/plant; 2.53, 7.51 and 17.64 % for No. of seeds/capsule;

4.34, 13.89 and 29.74 for seed index; 11.51, 35.71 and 114.78 % for seed yield/plant; 11.45, 35.66 and 114.84 % for seed yield/fad; 4.68, 13.21 and 37.09 for biological yield/fad; 1.91, 9.13 and 20.18 for oil seed percentage in addition to 13.34, 47.26 and 157.75 % for oil yield/fad. Many investigators came out with similar results as El-Shimy *et al.,* (1993), Mostafa *et al*., (2003), Husain *et al.,* (2009), El-Nagdy *et al*., (2010), Fataneh *et al*., (2012), Sharma *et al*., (2012), Upadhyay *et al.,* (2012), Hassan and Shaler (2013) Homayouni *et al*., (2013), Singh *et al*., (2013), Soethe *et al*., (2013), Kariuki *et al*., (2014), Kumar *et al*., (2014), Lilian *et al*., (2014), Andruszczak *et al*., (2015), Gudeta (2015), Padamchand (2015) and Patel (2016).

Table 4: Mean values of seed yield and its related traits as well as biological yield/fad (kg) for the flax as affected by irrigation intervals and nitrogen fertilizer rates (combined analysis over 2015/2016 and 2016/2017 seasons).

Treatment		Number of capsules /plant	Number of seeds/ capsule	Seed index (g)	Seed yield/ plant (g)	Seed yield/fad (kg)	Biological yield/fad (kg)	Oil seed content %	Oil yield (kg/fad)
Irrigation interval									
21 days		11.40	8.000	4.960	0.463	489.9	5303.8	34.78	173.4
28 days		10.46	7.750	4.781	0.398	421.2	4962.9	33.63	144.4
35 days		8.89	7.113	4.436	0.287	304.2	4199.5	31.53	97.8
LSD at 5%		1.10	0.170	0.423	0.091	89.7	466.2	1.62	36.3
Nitrogen fertilizer rate									
Untreated		8.17	6.9	4.039	0.23	243.3	3943.2	29.73	72.9
30 kg N/fad		10.33	7.55	4.601	0.364	385.3	4775.2	32.74	127.6
45 kg N/fad		11.00	7.917	5.022	0.443	469.0	5164.0	35.06	165.8
60 kg N/fad		11.50	8.117	5.24	0.494	522.7	5405.9	35.73	187.9
LSD at 5%		0.79	0.12	0.315	0.061	76.3	302.3	1.16	29.8
The interaction effect between irrigation interval and nitrogen fertilizer rate									
21 days	Untreated	9.15	7.300	4.185	0.279	295.6	4390.6	31.035	91.8
	30	11.55	8.000	4.875	0.450	476.8	5260.3	34.505	164.7
	45	12.2	8.300	5.296	0.536	567.9	5657.9	36.555	207.7
	60	12.7	8.400	5.483	0.585	619.3	5906.3	37.02	229.3
28 days	Untreated	8.3	7.050	4.026	0.236	249.5	4095.0	29.95	74.7
	30	10.4	7.700	4.654	0.372	394.2	4887.7	33.185	130.9
	45	11.25	8.050	5.134	0.465	492.7	5310.7	35.37	174.3
	60	11.9	8.200	5.308	0.518	548.3	5558.3	36.005	197.5
35 days	Untreated	7.05	6.350	3.906	0.175	184.9	3343.9	28.19	52.1
	30	9.05	6.950	4.275	0.269	285.0	4177.5	30.535	87.1
	45	9.55	7.400	4.635	0.327	346.5	4523.5	33.25	115.3
	60	9.9	7.750	4.928	0.378	400.5	4753.0	34.15	136.8
LSD at 5%		N.S.	N.S.	N.S.	N.S.	132.1	523.5	N.S.	51.6

The interaction between irrigation intervals and nitrogen fertilizer rates had significant effect on seed, biological and oil yield/fad in the combined, by means that dependent effect was found concerning the two studied factors in these cases. It must be observed that the heaviest seed, biological and oil yield/fad was obtained by irrigation flax plants every 21 days and supplied with 60 kg N/fad with the mean values of 619.3, 5906.3 and 229.3 kg in combined analysis, respectively. Similar results were also obtained by Husain *et al*., (2009), Sharma *et al*., (2012), Hassan and Shaler (2013 b), Padamchand (2015) and Patel (2016).

C: Anatomical Studies:

C1: tissues area:

Estimates of different tissues area (mm^2) per cross section (c.s.) at the middle part of flax stem as affected by irrigation intervals and nitrogen fertilizer rates are presented in Table 5.

Regarding irrigation intervals effect, results revealed that remarkable reduction had happened with elongate irrigation interval until every 35 days, by means that irrigated flax plants every 21 days achieved maximum areas for total cross section area (7.72 mm^2), cortex area (0.64 mm^2), fiber area (1.39 mm^2), xylem area (3.11 mm^2) and pith area (2.58 mm^2), in addition to fiber index (159.9 mm^3) which indicated the fiber quantity per flax plant in volume. Meanwhile, the lowest estimates were obtained by irrigation every 35 days which recorded the following measurements: total cross section area (5.30 mm^2), cortex area (0.43 mm^2), fiber area (0.35 mm^2), xylem area (2.32 mm^2), pith area (2.20 mm^2), and the minimum fiber index (64.9 mm^3), Irrigation every 28 days ranked second after every 21 days and ranked intermediate position between the shorted interval (every 21 days) and the longest one (every 35 days). The above mentioned results illustrated the more important role of water in flax growth. The present findings are in accordance with those recorded by Kayembe (2015) revealed that irrigated kenaf plants significantly increased all anatomical manifestations, *i.e.* total cross section area (mm^2), cortex area (mm^2), fiber area (mm^2), xylem area (mm^2) and pith area (mm^2) and fiber index (cm^3) as compared to rainfed kenaf plant, was found variation between irrigation intervals among the different tissues area per cross sections (Fig 1).

Table 5: Mean values of different tissues area per cross section (C.S.) at the middle of stems and fiber index estimates of flax as affected by irrigation intervals and nitrogen fertilizer rates during 2016/2017 season.

Trait / Treatment	Total cross section area (mm^2)	Cortex area (mm^2)	Fiber area (mm^2)	Xylem (mm^2)	Pith (mm^2)	Fiber index (mm^3)
Irrigation interval						
Every 21 days	7.72	0.64	1.39	3.11	2.58	159.9
Every 28 days	7.01	0.57	1.02	2.96	2.46	133.0
Every 35 days	5.30	0.43	0.35	2.32	2.20	64.9
Nitrogen fertilizer rate						
Untreated	7.19	0.50	0.69	2.98	3.02	93.6
30 kg N/fad	7.25	0.72	0.76	3.02	2.75	97.2
45 kg N/fad	7.47	0.85	0.91	3.19	2.52	110.2
60 kg N/fad	7.81	0.92	1.01	3.33	2.55	114.9

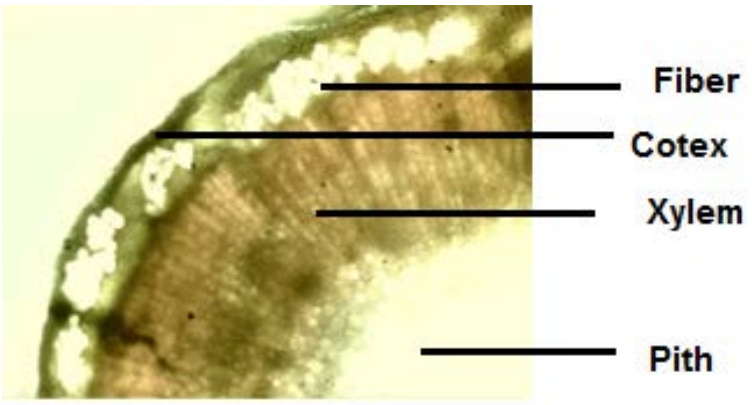
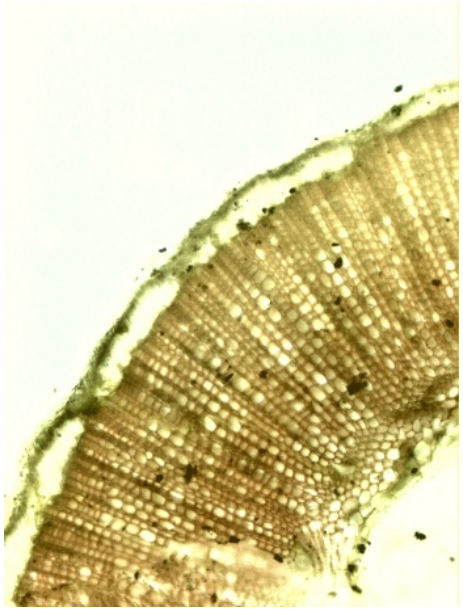
Irrigation every 21 days	
Irrigation every 28 days	
Irrigation every 35 days	

Fig 1: Cross section as affected by irrigation interval for the flax in the middle region of technical stem length at full maturity during 2016/2017 season.

Effect of nitrogen fertilizer rates, cross section area ranged from 7.19 to 7.81 mm^2, cortex area ranged from 0.50 to 0.92 mm^2, fiber area ranged from 0.69 to 1.01 mm^2, xylem area ranged from 2.98 to 3.33 mm^2, and fiber index ranged from 93.6 to 114.9 mm^3 for the untreated and fertilized flax plants with 60 kg N/fad, respectively. In the sometime, pith area take the opposite direction in this case, where the greatest pith area (3.02 mm^2) was found in untreated and the lowest one occurred with added either 45 or 60 kg N/fad . These results due to the active role of nitrogen which this element play great role in plant growth by encourage cell division and cell size. Variation between nitrogen fertilizer rates was found among the different tissues area cross sections (Fig 2).The above mentioned results illustrated the more important role of nitrogen fertilizer in flax growth. The present findings are in accordance with those recorded by El-Shimy *et al*., (1993), Mostafa *et al*., (2003) and El-Nagdy *et al*., (2010).

C2: Percentage of different tissues per total cross section:

From Table 6, results exhibited that irrigation flax plants every 21 days achieved highest percentages in cortex (8.29 %) and fiber (18.01 %), but the maximum xylem (43.77 %) and pith (41.51 %) percentages had occurred when elongate irrigation interval at 35 days. Irrigated flax plants every 28 days caused intermediate tissues ratios between irrigation every 21 and 35 days approximately. The present findings are in accordance with those recorded by Kayembe (2015) revealed that irrigated kenaf plants significantly increased cortex % and fiber % as compared to rainfed kenaf plants. On the other hand, xylem % and pith % were decreased.

Nitrogen fertilizer rates effect, cortex and fiber percentages were increased with increasing nitrogen rate from untreated up to 60 kg N/fad, xylem percentages reported relatively equal estimates which it ranged from 41.45 to 42.64 %, while pith ratio was more wide (42.00 %) in the untreated and gradual reduction had happened and reached minimum (32.65 %) with applying 60 kg N/fad. The present findings are in accordance with those recorded by El-Shimy *et al*., (1993), Mostafa *et al*., (2003) and El-Nagdy *et al*., (2010).

Table 6: Percentage of different tissues per the corresponding total cross section area at the middle part of flax stems affected by irrigation intervals and nitrogen fertilizer rates during 2016/2017 season.

Trait Treatment	Cortex %	Fiber %	Xylem %	Pith %
Irrigation interval				
Every 21 days	8.29	18.01	40.28	33.42
Every 28 days	8.13	14.55	42.23	35.09
Every 35 days	8.11	6.60	43.77	41.51
Nitrogen fertilizer rate				
Untreated	6.95	9.60	41.45	42.00
30 kg N/fad	9.93	10.48	41.66	37.93
45 kg N/fad	11.38	12.18	42.70	33.73
60 kg N/fad	11.78	12.93	42.64	32.65

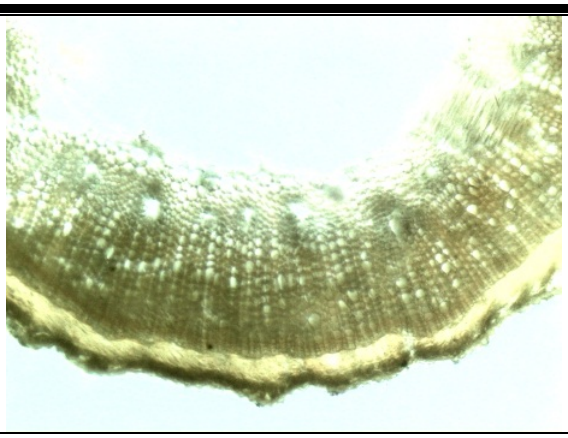
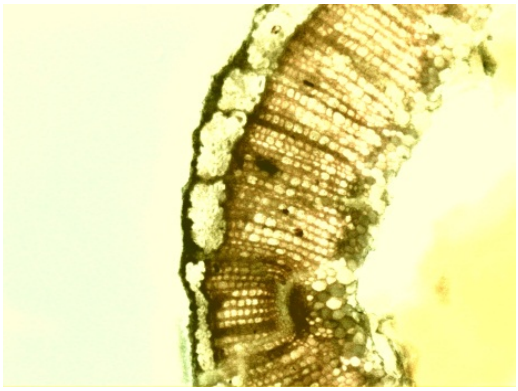
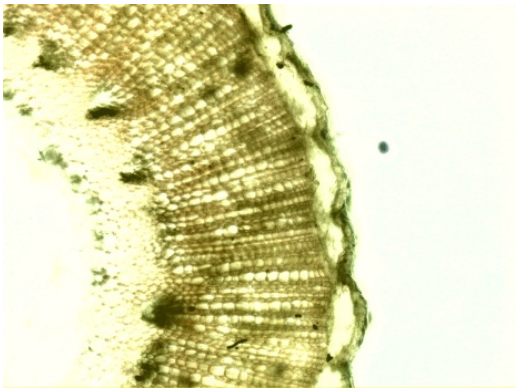
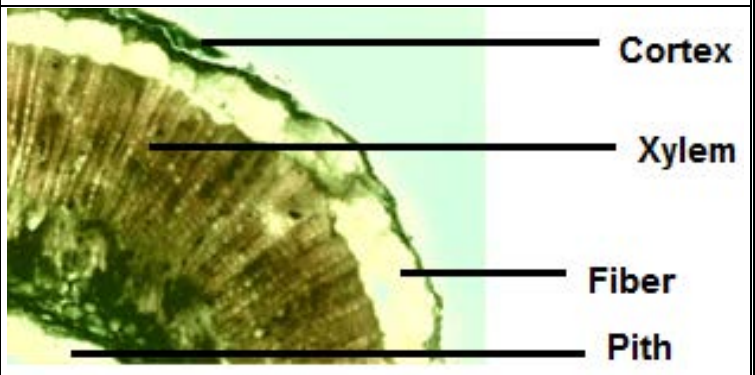
Untreated	
30 kg N/fad	
45 kg N/fad	
60 kg N/fad	

Fig 2: Cross section as affected by nitrogen fertilizer rates for the flax in the middle region of technical stem length at full maturity during 2016/2017 season.

Generally, anatomical manifestation studies confirmed the previous results of yield and yield components as affected by irrigation intervals and nitrogen fertilizer rates which discussed before. In another meaning, that irrigation flax plants every 21 days combined with added 60 or 45 kg N/fad performed maximum estimates of all studied characters except with fiber fineness (Nm) and either pith area or pith % which were in minimum values.

CONCLUSION

Generally, it could be concluded that flax plants need the water for cell division, elongation, photosynthesis, bio processes in cytoplasm, transfer and distribution of carbohydrate, hormones and minerals salts. Moreover, flax plants at short irrigation interval (every 21 days) achieved an increment in majority characters, except fiber fineness of flax which take the opposite trend and consequently coarse fiber. In the same time, increasing nitrogen rates encourage vegetative plant growth, which return back for increasing plant yield and anatomical manifestations, look for also exception in fiber fineness that more nitrogen amount caused more coarse fiber. It could be summarized that irrigated flax plants (Giza 10 *cv.*) every 21 or 28 days and soil fertilized with 45 or 60 kg N/fad to maximized quantity and quality of straw and seed yield characters.

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تأثير فترات الري ومعدلات السماد النيتروجيني على محصول الكتان وبعض الصفات التشريحية

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الملخص العربى

أجريت تجربتان حقليتان في محطة البحوث الزراعية بالجميزة، محافظة الغربية، مركز البحوث الزراعية، مصر. خلال الموسمين الشتويين 2016/2015 و 2017/2016، لدراسة تأثير ثلاث فترات للري (الري كل 21 – 28 – 35 يوم) ووأربع مستويات من السماد النيتروجيني (بدون إضافة – 30 – 45 – 60 كجم نيتروجين/فدان) على كمية ونوعية القش والبذور ودراسة المظاهر التشريحية في منتصف الساق الرئيسي لصنف الكتان جيزة 10. وكان التصميم التجريبي المستخدم هو القطع المنشقة مرة واحدة في ثلاث مكررات، حيث تم توزيع فترات الري في القطع الرئيسية، بينما تم توزيع مستويات التسميد النيتروجيني في القطع المنشقة. هذا وقد اشتملت هذه التجربة على 12 معاملة عبارة عن التوافق بين ثلاثة فترات من الري مع أربعة مستويات من التسميد النيتروجيني.

ويمكن تلخيص أهم النتائج فيما يلي:.

أشارت النتائج أن الإختلافات بين فترات الري تحت الدراسة كانت معنوية في جميع الصفات المدروسة خلال التحليل التجميعي لموسمي الدراسه. حقق ري نباتات الكتان كل 21 يوم أعلى القيم معنويا لصفات إرتفاع النبات الكلي، الطول الفعال، طول منطقة التفريع القمية، محصول القش/نبات، محصول القش/فدان، نسبة الألياف الكلية، محصول الإلياف/فدان، طول الألياف، عدد الكبسولات/نبات، عدد البذور/كبسولة، دليل البذرة، محصول البذور/نبات، محصول البذور/فدان، المحصول البيولوجي/فدان، محتوى البذور من الزيت و محصول الزيت/فدان بينما أعطت أقل القيم في نعومة الألياف. وعلي النقيض حقق الري كل 35 يوم أقل القيم في الصفات المدروسة ما عدا نعومة الألياف. ري الكتان كل 28 يوم أعطى قيم متوسطة في كل الصفات المدروسة بدون معنوية مع الري كل 21 يوم. معظم الصفات التشريحية المدروسة (المقطع العرضي الكلي للساق، مساحة القشرة، مساحة الألياف، مساحة الخشب، مساحة النخاع، دليل الألياف، النسبة المئوية للقشرة والنسبة المئوية للألياف) زادت مع ري نباتات الكتان كل 21 يوم على النقيض من ذلك إنخفضت النسبة المئوية للخشب والنسبة المئوية للنخاع.

تأثرت جميع الصفات المدروسة (إرتفاع النبات الكلي، الطول الفعال، طول منطقة التفريع القمية، محصول القش/نبات، محصول القش/فدان، نسبة الألياف الكلية، محصول الإلياف/فدان، طول الألياف، عدد الكبسولات/نبات، عدد البذور/كبسولة، دليل البذرة، محصول البذور/نبات، محصول البذور/فدان، المحصول البيولوجي/فدان، محتوى البذور من الزيت و محصول الزيت/فدان في التحليل التجميعي لموسمي الدراسة) معنوياً بزيادة معدل السماد النيتروجيني من كنترول حتى 60 كجم نيتروجين/فدان ما عدا صفة نعومة الألياف التي نقصت مع زيادة معدل السماد النيتروجيني في التحليل التجميعي. زيادة معدل السماد النيتروجيني الى 60 كجم

نيتروجين/فدان أدى الى زيادة معظم الصفات التشريحية المدروسة (المقطع العرضي الكلي للساق، مساحة القشرة، مساحة الألياف، مساحة الخشب، مساحة النخاع، دليل الألياف، النسبة المئوية للقشرة ،النسبة المئوية للألياف والنسبة المئوية للخشب) على النقيض من ذلك إنخفضت النسبة المئوية للنخاع.

أشارت النتائج إلى أن ري الكتان كل 21 يوم مع التسميد النيتروجيني بمعدل 60 كجم نيتروجين/فدان أعطت معنوياً أفضل القيم في صفات محصول البذور/فدان، المحصول البيولوجي/فدان ومحصول الزيت/فدان في التحليل التجميعي لموسمي الدراسة. على العكس من ذلك أعطت ألياف أقل نعومة.

توصي النتائج بري الكتان صنف جيزة 10 كل 21 أو 28 يوم والتسميد النيتروجيني بمعدل 45 أو60 كجم نيتروجين/فدان حيث زاد محصول القش والبذور بوحدة المساحة والصفات المرتبطة بها كماً ونوعاً.

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