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Effect of Nitrogen Fertilizer Rates and Plant Density on Straw, Fiber Yield and Anatomical Manifestations of Some Flax Cultivars

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Abstract

Two field experiments were carried out at the Experimental Farm at Gemmeiza Agriculture Research Station, Agricultural Research Center, Egypt, during two successive winter growing seasons of 2018/2019 and 2019/2020 to study the response of three flax cultivars, *i.e*. Sakha 3, Giza 11 and Giza 12 to three nitrogen fertilizer rates (30, 50 and 70 kg N/fed) and three plant densities (1500, 2000 and 2500 seeds/m^2) and their effect on straw and fiber yield and its related traits as well as anatomical manifestations for flax stem at middle region. The experimental design was laid out using split-split plot design in four replications. Flax cultivars were distributed in the main plots, whereas nitrogen fertilizer rates were arranged at random in sub-plots and plant densities treatments were assigned at random in sub-sub plots. The sub-sub plot area was 9 m^2. Sakha 3 cultivar significantly produced the maximum total plant height, technical stem length, total fiber percentage, fiber yield/plant, fiber yield/fed, fiber length and fiber fineness in both seasons. Meanwhile, the highest No. of basal branches/plant, straw yield/plant and straw yield/fed in both seasons were recorded with Giza 12 cultivar. Meanwhile, Giza 11 cultivar gave the thickness stem diameter in both seasons. Increasing nitrogen fertilizer rates from 30 to 70 kg N/fed caused significant increases in all straw and fiber yield and its related traits of flax, except fiber fineness was significantly decreased with increasing nitrogen rates in both seasons. Increasing plant densities from 1500 to 2500 seeds/m^2 caused markedly increment in total plant height, technical stem length, straw yield/fed, total fiber percentage, fiber yield/fed, fiber length and fiber fineness during both seasons. On the other hand, No. of basal branches/plant, stem diameter, straw yield/plant and fiber yield/plant were significantly decreased by increasing plant densities during both seasons. The first order interactions between treatments Sakha 3 X 70 kg N/fed, Sakha 3 X 2500 seeds/m^2 and 70 kg N/fed X 2500 seeds/m^2 as well as the second order interaction between treatments Sakha 3 X 70 kg N/fed X 2500 seeds/m^2 were significantly recorded the highest total plant height, technical stem length, fiber yield/fed and fiber length as compared with the others interactions in both seasons. While, the maximum fiber yield/fed were recorded from the first order interactions between treatments Sakha 3 X 70 kg N/fed, Sakha 3 X 2500 seeds/m^2 and 70 kg N/fed X 2500 seeds/m^2 as well as the second order interaction between treatments Sakha 3 X 70 kg N/fed X 2500 seeds/m^2. Data illustrated an increase in each of total cross section area, cortex area, fiber area, xylem area, fiber index per plant, cortex % and xylem % in all flax cultivars under study (Sakha 3, Giza 11 and Giza 12) as affected by fertilized flax plants with 70 kg N/fed and plant density at 1500 seeds/m^2. It could be concluded that Sakha 3 cultivar and fertilizing by 70 kg N/fed with plant density of 2500 seeds/m^2 to maximizing fiber yield/fed and quality.

Keywords: flax, cultivars, Nitrogen fertilizer, plant densities, straw yield, fiber yield, anatomical manifestations.

Introduction

In Egypt, Flax (*Linum usitatissimum* L.) ranked second after cotton as a fiber crop regarding the cultivated area and industry importance. The fibers, which extracted from flax stem by retting process is a good row material for textile in addition to the oil obtained from seeds. Therefore, many industries had been established on flax fiber and seeds. Fresh linseed oil is used as human food and after boiling and treated chemically used as painting ink and varnish industries. Moreover, linseed cake is a valuable protein source to poultry and ruminants. Recently, the cultivated area by flax in Egypt tended to decrease in the valley lands due to great competition with other major winter crops. Flax yield potential could be sustained through the use of high yielding varieties with application of the best agronomic practices such as nitrogen fertilizer rates and plant densities.

Varietal differences among flax cultivars have been reported by many investigators as **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; Andruszczak *et al.* 2015; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; Gupta *et al.* 2017; Fila *et al.* 2018; Abdel-Kader and Mousa 2019; Emam 2019 and Emam 2020** they found that significant differences among the test cultivars in straw and fiber yield/fed and its related traits.

Determination of the required rate of nitrogen fertilizer of flax plants is the main important practices of great contribution for the highest production and better quality, as well as nitrogen is a key element for flax productivity. Several investigations reported that increasing nitrogen fertilizer rates caused significant increases in flax straw and fiber yield/fed and its related traits. On the other hand, fiber fineness was significantly decreased **Omar and Ash-Shormillesy 2006; Ahmed 2010; El-Nagdy *et al.* 2010; Andruszczak *et al.* 2015; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; El-Shimy *et al.* 2017; Gupta *et al.* 2017; El-Gedwy *et al.* 2018; Abdel-Kader and Mousa 2019 and Emam 2019.**

The effect of plant density on straw and fiber yield as well as their quality was studied by many investigators as, **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; Fila *et al.* 2018; Ganvit *et al.* 2019 and Teshome *et al.* 2020,** who found significant increase in total plant height, technical stem length, straw yield/fed, total fiber percentage, fiber yield/fed, fiber length and fiber fineness, but significant decreased in No. of basal branches/plant, stem diameter, straw yield/plant and fiber yield/plant with increasing plant density.

Regarding anatomical study, varietal differences had been found in all anatomical tissues per cross section for flax stem at middle region of technical length, *i.e.* total cross section, cortex, fiber, xylem and pith areas in addition to fiber index **(El-Shimy *et al*. 1993 and 2019).** Nitrogen fertilizer affected anatomical manifestations as reported by **El-Shimy *et al*. 1993; El-Nagdy *et al.* 2010 and El-Gedwy *et al*. 2018,** who illustrated that gradual increment for all anatomical characters due to increasing nitrogen fertilizer rates except with pith area which decreased in this case. Increase plant density caused somewhat decrements in anatomical tissue area in the cross section for flax stem, while more seeding rate (plant density) achieved more technical stem length (searching for light) which compensate the little tissues area per cross section and increase fiber index **(El-Shimy *et al*. 1993).**

The aim of this investigation was designed to study the effect of nitrogen fertilizer rates and plant densities on straw and fiber yield and its components of flax cultivars, in addition to their quality as well as anatomical manifestations for flax stem at middle region of technical length in farm at El-Gemmeiza Research Station, Gharbia Governorate, Egypt.

Materials and Methods:

Two field experiments were conducted at the Experimental Farm at Gemmeiza Agriculture Research Station, Agricultural Research Center, Egypt, during two successive winter growing seasons of 2018/2019 and 2019/2020 to study the response of three flax cultivars to three nitrogen fertilizer rates (30, 50 and 70 kg N/fed) with three plant densities; 1500, 2000 and 2500 seeds/m^2 and their effect on straw and fiber yield and its related traits.

The cultivar seeds were obtained from Fiber Crops Research Section, Field Crops Research Institute, Agricultural Research Center, Egypt and its pedigree was shown in **Table 1.**

Table 1: Type and pedigree of studied flax cultivars.

Flax cultivar	Type	Pedigree
Sakha 3	Fiber	I.2596 x Belinka
Giza 11	dual purpose	Giza 8 x S.2419
Giza 12	dual purpose	S.2419 x S.148/6/1

Nitrogen fertilizer was applied in form of urea (46 % N), and divided into two equal parts which applied before the first and second irrigations in both seasons.

The seeding rates (kg/fed) from plant densities treatments (No. of seeds/m^2) for the studied flax cultivars as shown in **Table 2.**

Table 2. Planting density of flax cultivars (seeds/m^2) and their corresponding number of seeds per 3 m long of row and seeding rates (kg/fed).

Flax cultivar	Plant density (No. of seeds/m^2)	No. of seeds per 3 m long of row	Seeding rates (kg/fed).
Sakha 3	**1500**	675	33.08
	2000	900	44.10
	2500	1125	55.13
Giza 11	**1500**	675	48.83
	2000	900	65.10
	2500	1125	81.38
Giza 12	**1500**	675	46.31
	2000	900	61.74
	2500	1125	77.18

Soil analysis:

Soil texture of the experimental site was silty clay loam texture with pH nearly of 8.0. Soil samples were taken before sowing of crop to depth of 0-30 cm for chemical and mechanical properties analysis of the experimental soil were determined according to the standard procedures described by **Rowell (1995)** and represented in **Table 3** in each of two growing seasons.

The preceding summer crop in two seasons was rice (*Oryza sativa*, L.). The experimental design was laid out using split-split plot design in four replications. Each of the three flax cultivars were distributed in the main plots, whereas the three nitrogen fertilizer rates were arranged at random in sub-plots and the three plant densities treatments were assigned at random in sub-sub plots. The experimental unit comprised 9 m^2 with 3 m long and 3 m width, forming 20 rows of 15 cm between rows. Flax seeds were sown on November 1th and 11th in the first season (2018/2019) and the second season (2019/2020), respectively. Phosphorous fertilizer was applied in form of calcium super phosphate (12.5 %

P_2O_5) at a level of 100 kg/fed during soil preparation in each season. The others recommended agronomic practices of growing flax were applied in the manner prevailing in the region were practiced.

Table 3. Chemical and mechanical properties of the experimental soil units at flax planting during 2018/2019 and 2019/2020 seasons.

Properties	Season	
	2018/2019	2019/2020
Chemical analysis:		
E.C. (ds/m)	3.39	3.42
pH (1 :2.5)	7.95	7.92
Ca Co_3 %	1.94	2.15
O.M %	2.06	1.92
N % (total)	0.130	0.111
P % (total)	0.093	0.085
K % (total)	0.125	0. 097
N (ppm) (available)	29.55	24.43
P (ppm) (available)	10.25	9.21
K (ppm) (available)	133.45	111.05
Mechanical analysis:		
Course sand %	4.55	5.22
Find sand %	10.33	9.89
Silt %	47.56	45.81
Clay %	37.56	39.08
Texture grade	**Silty Clay Loam**	

Studied traits:

At maturity, about 150 days from sowing date, ten guarded plants were taken randomly from each sub-sub plot for recording straw plant traits. Straw and fiber yield (kg/fed) were estimated according to yield from three meter square of each sub-sub plot. After harvesting and removing the capsules from plants in one meter square of each sub-sub plot, retting process took place at Fiber Crops Research Section, Gemmeiza Agriculture Research Station, Gharbia Governorate, Agricultural Research Center, Egypt. Straw from plants in one meter square of each sub-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 the woody part of stem.

A- Straw yield and its related traits:

Total plant height (cm), technical stem length of the main stem (cm), No. of basal branches/plant, stem diameter (mm), straw yield/plant (g) and straw yield/fed (kg).

B- Fiber yield and its related traits:

Total fiber percentage (%), fiber yield/plant (g), fiber yield/fed (kg), fiber length (cm) of the main stem and fiber fineness (Nm) determined using **Radwan and Momtaz (1966)** methods according to the following equation: **Nm = (N X L)/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 (2000 mm).

W = Weight of fibers in mg.

C- Anatomical manifestations:

In the second season (2019/2020), at maturity stage, while plants were standing in the field, samples of five plants were chosen from the main stems at middle region. 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 and then dehydrated in the following steps; 15 %, 30 %, 45 %, 60 %, 70 %, 80 %, 95 % 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 52c 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 method **Sass (1951)** for cutting **and Johanson (1940)** for pigmenting method.

C_1-Tissues area: total cross section area (mm^2), cortex area (mm^2), fiber area (mm^2), xylem area (mm^2) and pith area (mm^2) in addition to fiber index (mm^3) calculated from the product of fiber area (mm^2) per cross section X technical stem length (mm), this measurement represented the fiber which flax plant contain in volume.

C_2-Percentage of different tissues per cross section: cortex %, fiber %, xylem % and pith %.

Statistical analysis:

The analysis of variance was carried out according to the procedure described by **Gomez and Gomez (1984).** Data were statistically analyzed according to using the MSTAT-C Statistical Software Package **(Freed, 1991).** Where the F-test showed significant differences among means L. S. D. test at 0.05 level was used to compare between means.

Results and Discussion:

A- Straw yield and its related traits:

1) Effect of flax cultivars:

Results presented in **Table 4** showed that all straw yield and its related traits under study were differed significantly among the three flax cultivars during 2018/2019 and 2019/2020 seasons. The differences between flax cultivars Giza 11 and Giza 12 did not reach the level of significance in total plant height, technical stem length, straw yield/plant and straw yield/fed. The maximum total plant height and technical stem length were achieved by Sakha 3 during both seasons. Sakha 3 cultivar increased total plant height by 11.61 and 14.44 % in 2018/2019 season, corresponding to 9.56 and 11.78 % in 2019/2020season, over total plant height of Giza 12 and Giza 11 cultivars, respectively. Results may reveal the superiority of Giza 12 cultivar in No. of basal branches/plant, straw yield/plant and straw yield/fed in two seasons. Giza 11 and Giza 12 cultivars significantly increased straw yield/fed by 10.58 and 14.49 % in the first season, and by 13.23 and 16.75 % in second season, respectively compared to flax cultivar of Sakha 3. Giza 11 cultivar gave the thickness stem diameter in both seasons. Giza 12 and Giza 11 cultivars significantly increased stem diameter by 34.37 and 50.38 % in the first season, respectively, and by 34.44 and 43.68 % in the second season, respectively as compared to stem diameter of Sakha 3 cultivar. These differences in straw yield and its related traits of flax cultivars may be due to the genetic differences between flax cultivar of Sakha 3 (fiber flax type) and flax cultivars Giza 11 and Giza 12 (dual purpose type). As well as, It could be concluded that Giza 12 surpassed the other two flax cultivars to increase straw yield/fed may be due to more likely attributed to the increases in straw yield/plant and No. of basal branches/plant. These results in good accordance with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; Andruszczak *et al.* 2015; El-Refaey *et al.* 2015;; El-Borhamy 2016; Ibrahim *et al.* 2016; Gupta *et al.* 2017; Fila *et al.* 2018; Abdel-Kader and Mousa 2019; Emam 2019 and Emam 2020,** showed that cultivars markedly varied for all straw yield and its related traits of flax plants.

Table 4. Mean values of straw yield and its related traits of flax cultivars during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/plant (g)		Straw yield/fed (kg)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	103.32	94.33	77.23	70.03	1.528	1.354	1.318	1.234	1.931	1.833	3581.64	3351.75
Giza 11	90.28	84.39	70.24	66.52	2.077	1.908	1.982	1.773	2.154	2.059	3960.75	3795.03
Giza 12	92.57	86.10	70.99	67.28	2.709	2.491	1.771	1.659	2.251	2.145	4100.56	3913.28
L.S.D. at 5 %	**4.15**	**3.56**	**2.98**	**2.67**	**0.098**	**0.087**	**0.093**	**0.088**	**0.111**	**0.107**	**348.62**	**315.45**

2) Effect of nitrogen fertilizer rates:

Results in **Table 5** revealed that increasing nitrogen fertilizer rates from 30 up to 70 kg N/fed caused significant increments in all flax traits in both seasons. While, No. of basal branches/plant was not significantly affected by nitrogen fertilizer rates in both seasons. But, the differences between nitrogen fertilizer rates of 50 and 70 kg N/fed on technical stem length and stem diameter as well as among 30 and 50 kg N/fed on stem diameter were not significant in both seasons. Flax plants which fertilized by 70 kg N/fed produced significantly the maximum total plant height, technical stem length, stem diameter, straw yield/plant and straw yield/fed in both seasons. On the other hand, the lowest total plant height, technical stem length, stem diameter, straw yield/plant and straw yield/fed in two seasons were obtained from flax planting received 30 kg N/fed. The superiority ratios in the first season between the highest nitrogen rate (70 kg N/fed) and each of 50 and 30 kg N/fed were 4.08 and 9.70 % for total plant height; 3.55 and 9.36 % for technical stem length; 2.47 and 6.49 % for stem diameter; 11.40 and 31.49 % for straw yield/plant in addition to 11.77 and 33.04 % for straw yield/fed, respectively. The excess ratios in the second season when flax received 70 kg N/fed over each of 50 and 30 kg N/fed were 3.96 and 9.59 % for total plant height; 3.53 and 9.14 % for technical stem length; 2.94 and 7.91 % for stem diameter 8.95 and 30.87 % for straw yield/plant in addition to 8.38 and 32.02 % for straw yield/fed, respectively. The increase in growth traits associated with increasing nitrogen fertilization rates may be attributed to the role of nitrogen in enhancement meristematic activity and cell division, which caused increases in number and size of cells in flax stem. Also, the increases in straw yield/plant and straw yield/fed with increase in nitrogen fertilizer rates may be attributed to the increases in total plant height, technical stem length and stem diameter of flax plant. Many investigators came out with similar results as **Ahmed 2010; El-Nagdy *et al.* 2010; Andruszczak *et al.* 2015; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; El-Shimy *et al.* 2017; Gupta *et al.* 2017; El-Gedwy *et al.* 2018; Abdel-Kader and Mousa 2019 and Emam 2019.**

Table 5. straw yield and its related traits of flax as affected by nitrogen fertilizer rates during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Nitrogen rate (kg N/fed)	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/ plant (g)		Straw yield/fed (kg)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
30	90.82	84.07	69.36	64.80	2.027	1.811	1.634	1.492	1.813	1.720	3307.03	3125.72
50	95.72	88.62	73.25	68.31	2.100	1.926	1.698	1.564	2.140	2.066	3936.22	3807.69
70	99.63	92.13	75.85	70.72	2.187	2.017	1.740	1.610	2.384	2.251	4399.69	4126.64
L.S.D. at 5 %	**2.99**	**2.88**	**2.85**	**2.64**	**N.S.**	**N.S.**	**0.081**	**0.075**	**0.097**	**0.093**	**315.27**	**288.69**

3) Effect of plant densities treatments:

Results presented in **Table 6** revealed that the differences between the three plant densities were significant on all straw yield and its related traits during two seasons. Flax planting at highest plant density (2500 flax seeds/m^2) markedly gave the maximum total plant height, technical stem length and straw yield/fed in both seasons. On the other hand, the lowest total plant height, technical stem length and straw yield/fed in both seasons were recorded from flax planting under the lowest plant density (1500 seeds/m^2). Increasing plant density from 1500 to 2000 and 2500 seeds/m^2 significantly increased straw yield/fed by 17.36 and 28.03 % respectively, in the first season. The corresponding increases were 18.71 and 29.66 % in the second season for the respective densities. The increases in total plant height and technical stem length by increasing plant densities is mainly due to the increased intra-specific competition among flax plants for light and decrease in light penetration, interception and photosynthetic efficiency at higher densities as well as higher dense of plants excessive shade exist which help to produce more content of gibberellin in tissues and consequently higher plants formed. Such increase in straw yield could be due to the increase in total plant height and technical stem length as well as No. of flax plants/m^2 due to increasing plant densities. These results are in harmony with those reported by **Abd El-Mohsen *et al.* 2013; Andruszczak *et al.* 2015; Ganvit *et al.* 2019 and Teshome *et al.* 2020**. The greatest No. of basal branches/plant, stem diameter and straw yield/plant in both seasons were obtained from planting 1500 flax seeds/m^2. On the other hand, sowing flax at plant density of 2500 seeds/m^2 markedly recorded the lowest No. of basal branches/plant, stem diameter and straw yield/plant in two seasons. In the first season, flax planting at 1500 seeds/m^2 increased straw yield/plant by 13.50 and 29.50 % compared with the growing flax at plant densities of 2000 and 2500 seeds/m^2 respectively, the respective corresponding in the second season were 13.64 and 28.98 %.This trend could be explained on the fact that in case of low plant density produced resulted in low competition between plants for nutrient elements, soil moisture and sun light, plants would have better opportunity to produce more metabolite contents and positive effect on plant growth, especially No. of basal branches/plant, stem diameter, straw yield/plant. As well as, such increase in straw yield/plant at flax plant density of 1500 seeds/m^2 could be due to the increases in stem diameter and No. of basal branches/plant of flax. Such results agree with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd Eldaiem 2015; El-Borhamy 2016; Fila *et al.* 2018; Ganvit *et al.* 2019 and Teshome *et al.* 2020.**

Table 6. Mean values of straw yield and its related traits of flax as affected by plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Plant density (seeds/m^2)	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/ plant (g)		Straw yield/fed (kg)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1500	89.94	82.62	65.06	60.03	2.487	2.319	1.828	1.748	2.388	2.274	3370.94	3174.86
2000	94.32	87.35	71.53	66.80	2.212	1.920	1.695	1.547	2.104	2.001	3956.11	3768.75
2500	101.92	94.84	81.87	77.00	1.614	1.514	1.548	1.371	1.844	1.763	4315.89	4116.44
L.S.D. at 5 %	**2.35**	**2.19**	**2.25**	**2.06**	**0.076**	**0.069**	**0.072**	**0.068**	**0.092**	**0.087**	**305.24**	**281.25**

4) Effect of interaction between flax cultivars and nitrogen fertilizer rates

All straw yield and its related traits of flax were significantly affected by interaction between flax cultivars and nitrogen fertilizer during both seasons, as shown in **Table 7.** Sakha 3 cultivar when received 70 kg N/fed produced significantly the maximum total plant height (107.93 and 98.20 cm) and technical stem length (80.64 and 72.72 cm) in both seasons respectively. While, the lowest total plant height (86.15 and 79.98 cm) and technical stem length (67.22 and 63.30 cm) in the respective two seasons were obtained from flax planting Giza 11 cultivar with soil fertilized by 30 kg N/fed. Giza 12 cultivar under soil fertilized by 70 kg N/fed recorded the highest No. of basal branches/plant (2.810 and 2.633 basal branches), straw yield/plant (2.554 and 2.398 g) and straw yield/fed (4653.67 and 4373.42 kg) during both seasons respectively. Meanwhile, Sakha 3 cultivar with applied of 30 kg N/fed gave the lowest No. of basal branches/plant (1.463 and 1.290 basal branches), straw yield/plant (1.661 and 1.562 g) and straw yield/fed (3015.50 and 2791.50 kg) in both seasons respectively. Giza 11 cultivar when received 70 kg N/fed gave thickness stem diameter by 2.033 and 1.837 mm in two seasons respectively. On the other hand, thinnest stem diameter (1.263 and 1.183 mm) in both seasons respectively was obtained from Sakha 3 cultivar with soil fertilized by 30 kg N/fed. These results agree with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Andruszczak *et al.* 2015; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; Gupta *et al.* 2017; Abdel-Kader and Mousa 2019 and Emam 2019,** found that straw yield and its related traits were significantly affected by interaction between flax cultivars and nitrogen fertilizer rates.

Table 7. Mean values of straw yield and its related traits of flax as affected by interaction between flax cultivars and nitrogen fertilizer rates during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Nitrogen rate (kg N/fed)	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/ plant (g)		Straw yield/fed (kg)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	30	98.09	90.73	73.21	67.44	1.463	1.290	1.263	1.183	1.661	1.562	3015.50	2791.50
	50	103.94	94.06	77.83	69.93	1.520	1.367	1.321	1.238	1.946	1.881	3612.67	3494.83
	70	107.93	98.20	80.64	72.72	1.600	1.407	1.370	1.280	2.188	2.056	4116.75	3768.92
Giza 11	30	86.15	79.98	67.22	63.30	2.000	1.797	1.921	1.694	1.859	1.762	3418.83	3243.67
	50	90.39	84.91	70.46	66.88	2.080	1.917	1.993	1.788	2.193	2.116	4034.75	3903.83
	70	94.31	88.27	73.05	69.39	2.150	2.010	2.033	1.837	2.409	2.300	4428.67	4237.58
Giza 12	30	88.22	81.50	67.64	63.67	2.617	2.347	1.718	1.598	1.918	1.836	3486.75	3342.00
	50	92.84	86.88	71.47	68.12	2.700	2.493	1.778	1.665	2.282	2.201	4161.25	4024.42
	70	96.66	89.92	73.87	70.04	2.810	2.633	1.818	1.714	2.554	2.398	4653.67	4373.42
L.S.D. at 5 %		**5.18**	**4.99**	**4.94**	**4.57**	**0.154**	**0.132**	**0.140**	**0.130**	**0.168**	**0.161**	**546.06**	**500.03**

5) Effect of interaction between flax cultivars and plant densities treatments:

Results in **Table 8** indicated that interaction between flax cultivars and plant densities treatments was significant effect on all straw yield and its related traits of flax in both seasons. Sakha 3 cultivar with 2500 seeds/m^2 recorded the maximum total plant height (111.33 and 100.75 cm) and technical stem length (86.94 and 78.49 cm) in both seasons respectively. On the other hand, the lowest values of total plant height (84.77 and 78.14 cm) and technical stem length (62.57 and 58.19 cm) in the respective two seasons were recorded from Giza 11 cultivar at 1500 seeds/m^2. The greatest No. of basal branches/plant (3.173 and 3.033 basal branches) and straw yield/plant (2.577 and 2.431 g) in both seasons respectively, were obtained from Giza 12 cultivar at 1500 seeds/m^2 as well as, planting the same flax cultivar with 2500 seeds/m^2 significantly recorded the maximum straw yield/fed (4483.92 and 4310.50 kg) in two seasons respectively. Meanwhile, Sakha 3 cultivar gave the lowest No. of basal branches/plant (1.113 and 1.047 basal branches) and straw yield/plant (1.765 and 1.662 g) under plant density of 2500 seeds/m^2 as well as lowest straw yield/fed (3016.17 and 2825.58 kg) at plant density of 1500 seeds/m^2 in the respective two seasons. The thickness stem diameter (2.117 and 2.002 mm) was obtained by Giza 11 cultivar with 1500 seeds/m^2 in both seasons respectively. Whereas, the thinnest stem diameter (1.152 and 1.090 mm in the respective two seasons) was obtained from Sakha 3 cultivar at plant density of 2500 seeds/m^2. The results agree with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; Andruszczak *et al.* 2015; El-Borhamy 2016 and Fila *et al.* 2018,** which reported that there was significantly difference among interaction between flax cultivars and plant densities for straw yield and its related traits.

6) Effect of interaction between nitrogen fertilizer rates and plant densities treatments:

Results in **Table 9** showed that interaction effect among nitrogen fertilizer rates and plant densities treatments induced significant differences on all straw yield and its related traits except stem diameter during two seasons. The highest total plant height (106.51 and 98.75 cm), technical stem length (85.11 and 80.02 cm) and straw yield/fed (4929.58 and 4598.00 kg) in two seasons respectively were recorded from growing flax when received 70 kg N/fed at plant density of 2500 seeds/m^2. While, sowing flax with the same nitrogen fertilizer rate under plant density 1500 seeds/m^2 gave the maximum No. of basal branches/plant (2.587 and 2.473 basal branches) and straw yield/plant (2.676 and 2.535 g) in both seasons respectively. On the other hand, flax planting under soil fertilized by 30 kg N/fed with 1500 seeds/m^2 gave the lowest total plant height (84.83 and 78.14 cm), technical stem length (60.90 and 56.52 cm) and straw yield/fed (2902.58 and 2749.92 kg) in both seasons respectively, as well as, planting the flax with the same nitrogen fertilizer rate at 2500 seeds/m^2 recorded the lowest No. of basal branches/plant (1.547 and 1.463 basal branches) and straw yield/plant (1.575 and 1.492 g in two seasons respectively. The results reported here are in harmony with those obtained by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Andruszczak *et al.* 2015 and El-Borhamy 2016.**

Table 8. Mean values of straw yield and its related traits of flax as affected by interaction between flax cultivars and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Plant density (seeds/m^2)	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/ plant (g)		Straw yield/fed (kg)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	**1500**	97.13	88.82	69.15	62.64	1.833	1.630	1.469	1.379	2.115	2.056	3016.17	2825.58
	2000	101.50	93.42	75.60	68.96	1.637	1.387	1.333	1.231	1.915	1.781	3621.42	3390.92
	2500	111.33	100.75	86.94	78.49	1.113	1.047	1.152	1.090	1.765	1.662	4107.33	3838.75
Giza 11	**1500**	84.77	78.14	62.57	58.19	2.453	2.293	2.117	2.002	2.472	2.334	3488.83	3296.08
	2000	89.57	83.51	69.22	65.30	2.157	1.913	1.975	1.758	2.143	2.063	4037.00	3888.92
	2500	96.51	91.50	78.95	76.08	1.620	1.517	1.854	1.559	1.847	1.780	4356.42	4200.08
Giza 12	**1500**	87.92	80.89	63.47	59.25	3.173	3.033	1.899	1.863	2.577	2.431	3607.83	3402.92
	2000	91.89	85.13	69.78	66.15	2.843	2.460	1.777	1.652	2.255	2.157	4209.92	4026.42
	2500	97.91	92.28	79.73	76.43	2.110	1.980	1.638	1.462	1.922	1.847	4483.92	4310.50
L.S.D. at 5 %		**4.07**	**3.79**	**3.90**	**3.57**	**0.132**	**0.120**	**0.125**	**0.118**	**0.159**	**0.151**	**528.69**	**487.14**

Table 9. Mean values of straw yield and its related traits of flax as affected by interaction between nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Nitrogen rate (kg N/fed)	Plant density (seeds/m^2)	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/ plant (g)		Straw yield/fed (kg)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
30	**1500**	84.83	78.14	60.90	56.52	2.393	2.147	1.767	1.687	2.066	1.967	2902.58	2749.92
	2000	90.57	83.58	68.80	64.25	2.140	1.823	1.643	1.481	1.797	1.702	3354.67	3167.92
	2500	97.05	90.49	78.37	73.64	1.547	1.463	1.491	1.307	1.575	1.492	3663.83	3459.33
50	**1500**	90.77	83.26	65.97	60.75	2.480	2.337	1.838	1.754	2.422	2.319	3422.08	3234.42
	2000	94.22	87.30	71.67	66.85	2.200	1.923	1.702	1.556	2.137	2.042	4032.33	3896.67
	2500	102.19	95.30	82.13	77.33	1.620	1.517	1.553	1.381	1.862	1.836	4354.25	4292.00
70	**1500**	94.21	86.46	68.32	62.81	2.587	2.473	1.880	1.803	2.676	2.535	3788.17	3540.25
	2000	98.17	91.18	74.13	69.31	2.297	2.013	1.741	1.604	2.378	2.257	4481.33	4241.67
	2500	106.51	98.75	85.11	80.02	1.677	1.563	1.600	1.424	2.097	1.962	4929.58	4598.00
L.S.D. at 5 %		**4.07**	**3.79**	**3.90**	**3.57**	**0.132**	**0.120**	**N.S.**	**N.S.**	**0.159**	**0.151**	**528.69**	**487.14**

7) Effect of interaction between flax cultivars, nitrogen fertilizer rates and plant densities treatments:

Results in **Table 10** showed significant interaction effect between flax cultivars, nitrogen fertilizer rates and plant densities treatments under study during two experimental seasons on total plant height, technical stem length, straw yield/plant and straw yield/fed of flax. While, No. of basal branches/plant and stem diameter were not significantly affected by interaction in both seasons. The maximum total plant height (116.88 and 105.12 cm) and technical stem length (91.35 and 82.02 cm) in both seasons respectively were obtained by Sakha 3 cultivar under soil fertilized by 70 kg N/fed with plant density of 2500 seeds/m^2. Whereas, Giza 11 cultivar when received 30 kg N/fed at plant density of 1500 seeds/m^2 gave the lowest total plant height (80.22 and 73.58 cm) technical stem length and (58.57 and 54.75 cm) in both seasons respectively. The heaviest straw yield/plant (2.916 and 2.712 g) in both seasons respectively which obtained from Giza 12 cultivar with soil fertilized by 70 kg N/fed at plant density of 1500 seeds/m^2. Whereas, Sakha 3 cultivar when received 30 kg N/fed with plant density of 2500 seeds/m^2 gave the lightest values of straw yield/plant (1.525 and 1.413 g) in both seasons respectively. Giza 12 cultivar when received 70 kg N/fed by plant density of 2500 seeds/m^2 gave the maximum straw yield/fed (5105.50 and 4795.00 kg in two respective seasons). On the other hand, the minimum values of straw yield/fed (2554.75 and 2416.00 kg) in two seasons respectively which obtained from Sakha 3 cultivar when received 30 kg N/fed at plant density of 1500 seeds/m^2. The results agree with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Andruszczak *et al.* 2015 and El-Borhamy 2016.**

Table 10. Mean values of straw yield and its related traits of flax as affected by interaction between flax cultivar, nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	N rate	Plant density	Total plant height (cm)		Technical stem length (cm)		No. of basal branches /plant		Stem diameter (mm)		Straw yield/plant (g)		Straw yield/fed (kg)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	30	1500	91.86	84.62	65.11	59.62	1.750	1.520	1.413	1.334	1.822	1.753	2554.75	2416.00
		2000	97.03	90.51	72.32	67.11	1.560	1.330	1.291	1.163	1.635	1.521	3013.50	2774.25
		2500	105.37	97.06	82.21	75.59	1.080	1.020	1.084	1.053	1.525	1.413	3478.25	3184.25
	50	1500	98.35	89.09	70.29	63.05	1.830	1.650	1.475	1.386	2.168	2.098	3099.50	2871.25
		2000	101.74	93.03	75.95	68.88	1.620	1.400	1.333	1.244	1.923	1.824	3680.25	3620.50
		2500	111.74	100.07	87.25	77.86	1.110	1.050	1.156	1.083	1.746	1.721	4058.25	3992.75
	70	1500	101.18	92.75	72.05	65.25	1.920	1.720	1.518	1.418	2.355	2.316	3394.25	3189.50
		2000	105.73	96.73	78.52	70.88	1.730	1.430	1.376	1.286	2.186	1.999	4170.50	3778.00
		2500	116.88	105.12	91.35	82.02	1.150	1.070	1.215	1.135	2.023	1.853	4785.50	4339.25
Giza 11	30	1500	80.22	73.58	58.57	54.75	2.360	2.110	2.052	1.935	2.153	2.033	3042.25	2874.25
		2000	86.12	79.25	66.88	62.56	2.110	1.830	1.913	1.692	1.846	1.752	3483.25	3307.75
		2500	92.11	87.12	76.22	72.58	1.530	1.450	1.797	1.454	1.579	1.501	3731.00	3549.00
	50	1500	85.39	78.99	63.25	58.95	2.450	2.320	2.126	2.014	2.506	2.394	3536.50	3379.50
		2000	89.23	83.59	69.02	65.02	2.150	1.920	1.986	1.765	2.191	2.091	4127.25	3940.50
		2500	96.56	92.14	79.11	76.68	1.640	1.510	1.868	1.586	1.883	1.862	4440.50	4391.50
	70	1500	88.69	81.86	65.88	60.87	2.550	2.450	2.173	2.057	2.757	2.576	3887.75	3634.50
		2000	93.36	87.69	71.75	68.33	2.210	1.990	2.027	1.816	2.391	2.347	4500.50	4418.50
		2500	100.87	95.25	81.51	78.98	1.690	1.590	1.898	1.638	2.079	1.977	4897.75	4659.75
Giza 12	30	1500	82.42	76.23	59.02	55.19	3.070	2.810	1.835	1.793	2.222	2.114	3110.75	2959.50
		2000	88.57	80.99	67.21	63.07	2.750	2.310	1.725	1.587	1.911	1.833	3567.25	3421.75
		2500	93.68	87.28	76.68	72.76	2.030	1.920	1.593	1.415	1.621	1.562	3782.25	3644.75
	50	1500	88.57	81.69	64.36	60.25	3.160	3.040	1.914	1.862	2.593	2.466	3630.25	3452.50
		2000	91.68	85.27	70.03	66.64	2.830	2.450	1.786	1.658	2.298	2.212	4289.50	4129.00
		2500	98.26	93.68	80.03	77.46	2.110	1.990	1.635	1.474	1.956	1.925	4564.00	4491.75
	70	1500	92.76	84.76	67.02	62.31	3.290	3.250	1.949	1.934	2.916	2.712	4082.50	3796.75
		2000	95.43	89.12	72.11	68.73	2.950	2.620	1.819	1.710	2.557	2.426	4773.00	4528.50
		2500	101.78	95.88	82.48	79.07	2.190	2.030	1.686	1.498	2.188	2.055	5105.50	4795.00
L.S.D. at 5 %			**7.05**	**6.57**	**6.75**	**6.18**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**0.276**	**0.261**	**915.72**	**843.75**

B- Fiber yield and its related traits:

1) Effect of flax cultivars:

All fiber yield and its related traits were significantly affected by three tested flax cultivars under study, but the differences in total fiber percentage, fiber yield/plant and fiber yield/fed between Giza 11 and Giza 12 were not significant in both seasons, as shown in **Table 11.** Sakha 3 cultivar significantly produced the maximum total fiber percentage, fiber yield/plant, fiber yield/fed, fiber length and fiber fineness in both seasons. On the other hand, the lowest total fiber percentage, fiber yield/plant, fiber yield/fed, fiber length and fiber fineness were obtained from Giza 11 cultivar in both seasons. The superiority ratios in the first season between flax cultivar of Sakha 3 and each of Giza 12 and Giza 11 were 42.12 and 46.74 % for total fiber percentage; 22.13 and 32.12 % for fiber yield/plant; 24.35 and 32.82 % for fiber yield/fed; 4.07 and 7.89 % for fiber length in addition to 37.68 and 45.09 % for fiber fineness, respectively. The excess ratios in the second season when flax planting Sakha 3 cultivar over each of Giza 12 and Giza 11 cultivars were 43.58 and 49.66 % for total fiber percentage; 22.89 and 33.77 % for fiber yield/plant; 23.21 and 32.14 % for fiber yield/fed; 3.61 and 9.90 % for fiber length in addition to 39.17 and 46.89 % for fiber fineness, respectively. The differences among flax cultivars were mainly due to the differences in the genetical constituents between flax cultivar of Sakha 3 (fiber flax type) and flax cultivars of Giza 11 and Giza 12 (dual purpose type). As well as, the increase in fiber yield/fed of Sakha 3 cultivar may be due to the increases in total fiber percentage and fiber yield/plant. Also, the increase in fiber fineness with flax cultivar of Sakha 3 resulted from the decreases in fiber thickness. These results are reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; Fila *et al.* 2018 and Abdel-Kader and Mousa 2019,** indicated great variations in fiber yield and its related traits with flax cultivars.

Table 11. Mean values of fiber yield and its related traits of flax cultivars during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Total fiber (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	22.54	22.24	0.436	0.408	815.21	753.56	70.52	67.48	202.41	210.84
Giza 11	15.36	14.86	0.330	0.305	613.79	570.28	65.36	61.40	139.51	143.54
Giza 12	15.86	15.49	0.357	0.332	655.59	611.63	67.76	65.13	147.01	151.50
L.S.D. at 5 %	**1.16**	**1.07**	**0.037**	**0.031**	**63.25**	**59.87**	**1.51**	**1.38**	**6.23**	**5.11**

2) Effect of nitrogen fertilizer rates:

Results in **Table 12** showed that increasing nitrogen fertilizer rates from 30 and 50 to 70 kg N/fed caused significant increases in total fiber percentage, fiber yield/plant, fiber yield/fed and fiber length of flax in both seasons. On the other hand, fiber fineness which significantly decreased with increasing nitrogen rates, but the differences in total fiber percentage between 30 and 50 kg N/fed as well as among 50 and 70 kg N/fed not reach the level of significance in both seasons. The maximum total fiber percentage, fiber yield/plant, fiber yield/fed and fiber length in both seasons were obtained when flax planting under soil fertilizer by 70 kg N/fed. Whereas, flax planting with 30 kg N/fed significantly gave the minimum total fiber percentage, fiber yield/plant, fiber yield/fed and fiber length in two seasons. The superiority ratios in the first season between the highest nitrogen rate (70 kg N/fed) and each of 50 and 30 kg N/fed were 3.72 and 9.43 % for total fiber percentage; 15.83 and 44.41 % for fiber yield/plant; 16.28 and 46.21 % for fiber yield/fed in addition to 3.30 and 9.56 % for fiber length, respectively. The increase ratios in the second season when flax received 70 kg N/fed over each of 50 and 30 kg N/fed were 4.27 and 9.89 % for total fiber percentage; 13.73 and 43.97 % for fiber yield/plant; 12.82 and 45.64 % for fiber yield/fed in addition to 3.35 and 8.93 % for fiber length, respectively. The increase in the fiber length with increasing nitrogen fertilizer levels might be due to increase in technical stem length. In addition to, the increase in fiber yield/fed of flax due to the increase in nitrogen rates is attributed to the increases in total plant height, technical stem length, stem diameter, straw yield/plant, straw yield/fed, total fiber percentage and fiber yield/plant. These results are in harmony with those obtained by **Omar and Ash-Shormillesy 2006; Ahmed 2010; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; El-Shimy *et al.* 2017; Gupta *et al.* 2017; El-Gedwy *et al.* 2018 and Abdel-Kader and Mousa 2019.** The softness fiber fineness was recorded from flax planting when received 30 kg N/fed being 169.72 and 174.81 Nm in both seasons respectively. On the other hand, the coarser fiber with fiber fineness was obtained from flax planting with 70 kg N/fed by 156.42 and 162.50 Nm in both season, respectively. The applying of 50 and 70 kg N/fed induced a significant decreases in fiber fineness over 30 kg N/fed by 4.08 and 7.84 %, in the first season and by 3.56 and 7.04 %, in the second season, respectively. The decrease in fiber fineness with increasing in nitrogen fertilizer rates may be attributed to increase in fiber thickness. The finding is agreement with those obtained by **El-Nagdy *et al.* 2010; El-Refaey *et al.* 2015; El-Shimy *et al.* 2017 and El-Gedwy *et al.* 2018**.

Table 12. Mean values of fiber yield and its related traits of flax as affected by nitrogen fertilizer rates during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Nitrogen rate (kg N/fed)	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Total fiber (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
30	17.07	16.68	0.304	0.282	560.45	516.51	64.52	61.72	169.72	174.81
50	18.01	17.58	0.379	0.357	704.71	666.75	68.43	65.05	162.79	168.58
70	18.68	18.33	0.439	0.406	819.42	752.22	70.69	67.23	156.42	162.50
L.S.D. at 5 %	**1.03**	**0.99**	**0.026**	**0.024**	**56.57**	**52.18**	**1.17**	**0.98**	**4.19**	**4.02**

3) Effect of plant densities treatments:

Results in **Table 13** show that increasing plant density from 1500 to 2500 seeds/m^2 caused significantly increment in total fiber percentage, fiber yield/fed, fiber length and fiber fineness during both seasons. On the other hand, fiber yield/plant was significantly decreased by increasing plant density from 1500 to 2500 seeds/m^2 in both seasons. Flax sowing at 2500 seeds/m^2 significantly produced the maximum total fiber percentage, fiber yield/fed, fiber length and fiber fineness as well as gave the lightest fiber yield/plant (0.346 and 0.327 g) in both seasons. On the other hand, flax planting at 1500 seeds/m^2 gave the lowest total fiber percentage, fiber yield/fed, fiber length and fiber fineness as well as gave the heaviest fiber yield/plant in both seasons. The superiority ratios in the first season between sowing flax at plant density of 2500 seeds/m^2 and each of 2000 and 1500 seeds/m^2 were 3.24 and 11.85 % for total fiber percentage; 13.22 and 44.30 % for fiber yield/fed; 15.23 and 27.17 % for fiber length in addition to 7.43 and 19.24 % for fiber fineness, respectively. The increase ratios in the second season when flax growing at 2500 seeds/m^2 over each of 2000 and 1500 seeds/m^2 were 4.79 and 14.06 % for total fiber percentage; 15.04 and 48.84 % for fiber yield/fed; 15.06 and 28.02 % for fiber length in addition to 5.28 and 16.85 % for fiber fineness, respectively. Flax sowing at plant density of 2500 seeds/m^2 in 2018/2019 season caused significantly decreased in fiber yield/plant by 8.95 and 12.85 % compared with the flax growing at plant density of 2000 and 1500 seeds/m^2, respectively. In the second season, the corresponding decreases in fiber yield/plant were 6.84 and 10.90 %. The decreases in fiber yield/plant with increasing plant densities from 1500 to 2500 seeds/m^2 could be due to the decreases in straw yield/plant. Such increases in fiber yield/fed at 2500 seeds/m^2 could be due to the increase in No. of flax plants/m^2, straw yield/fed and total fiber percentage of flax. It was clear that the increases in fiber length with plant density of 2500 seeds/m^2 may be due to the increases in total plant height and technical stem length. The increase in fiber fineness with increasing in plant densities treatments may be attributed to decrease in fiber thickness. The finding is agreement with those obtained by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et al.* 2013; Abd Eldaiem 2015; El-Borhamy 2016 and Fila *et al.* 2018.**

Table 13. Mean values of fiber yield and its related traits of flax as affected by plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Plant density (seeds/m^2)	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Total fiber (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1500	16.79	16.29	0.397	0.367	560.75	511.73	60.33	57.18	148.06	154.31
2000	18.19	17.73	0.380	0.351	714.68	662.10	66.58	63.62	164.33	171.27
2500	18.78	18.58	0.346	0.327	809.16	761.65	76.72	73.20	176.54	180.31
L.S.D. at 5 %	**0.95**	**0.93**	**0.021**	**0.018**	**54.19**	**48.73**	**1.14**	**0.93**	**4.11**	**3.87**

4) Effect of interaction between flax cultivars and nitrogen fertilizer rates:

Interaction effect between flax cultivars and nitrogen fertilizer rates was significant on total fiber percentage, fiber yield/plant, fiber yield/fed, fiber length and fiber fineness of flax in two growing seasons, as shown in **Table 14.** Sakha 3 cultivar with received 70 kg N/fed recorded the highest total fiber percentage (23.34 and 23.13 %), fiber yield/plant (0.509 and 0.474 g), fiber yield/fed (966.20 and 876.04 kg) and fiber length (73.76 and 70.03 cm) in both seasons respectively. While, the lowest total fiber percentage (14.64 and 14.05 %), fiber yield/plant (0.270 and 0.246 g), fiber yield/fed (502.62 and 457.83 kg) and fiber length (62.28 and 58.23 cm) were obtained from Giza 11 cultivar with soil fertilized by 30 kg N/fed in the respective two seasons. Sakha 3 cultivar when received 30 kg N/fed significantly produced the softness fiber fineness (211.67 and 218.63 Nm) in two seasons respectively. Whereas, Giza 11 cultivar and soil fertilized by 70 kg N/fed gave the coarser fiber with fiber fineness 134.43 and 138.97 Nm in both seasons respectively. These results are in agreement with that obtained by **Omar and Ash-Shormillesy 2006; Ahmed 2010; El-Refaey *et al.* 2015; El-Borhamy 2016; Ibrahim *et al.* 2016; Gupta *et al.* 2017 and Abdel-Kader and Mousa 2019,** found that fiber yield and its related traits were significantly affected by interaction between flax cultivars and nitrogen fertilizer rates.

5) Effect of interaction between flax cultivars and plant densities treatments:

As shown in **Table 15** interaction between flax cultivars and plant densities on total fiber percentage, fiber yield/plant, fiber yield/fed, fiber length and fiber fineness were significant during both seasons. The greatest total fiber percentage (23.52 and 23.44 %), fiber yield/fed (970.51 and 903.83 kg), fiber length (79.74 and 75.52 cm) and fiber fineness (226.57 and 231.83 Nm) in both seasons respectively were obtained from Sakha 3 cultivar at plant density of 2500 seeds/m^2 also, the same flax cultivar with 1500 seeds/m^2 recorded the maximum fiber yield/plant (0.449 and 0.428 g) in both seasons respectively. Meanwhile, Giza 11 cultivar with 1500 seeds/m^2 gave the lowest total fiber percentage (14.23 and 13.66 %), fiber yield/fed (498.30 and 451.65 kg), fiber length (57.86 and 53.38 cm) and fiber fineness (129.70 and 134.37 Nm) in both seasons respectively, as well as, the same flax cultivar with 2500 seeds/m^2 recorded the lowest fiber yield/plant (0.301 and 0.285 g) in both seasons respectively. These results in good accordance with those reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010; Abd El-Mohsen *et***

***al.* 2013; Abd Eldaiem 2015; El-Borhamy 2016 and Fila *et al.* 2018,** found that fiber yield and its related traits were significantly affected by flax cultivars and plant densities interaction.

Table 14. Mean values of fiber yield and its related traits of flax as affected by interaction between flax cultivars and nitrogen fertilizer rates during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Nitrogen rate (kg N/fed)	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Fiber fineness (Nm)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	30	21.49	21.19	0.356	0.329	651.19	594.96	66.70	65.02	211.67	218.63
	50	22.80	22.41	0.442	0.419	828.23	789.67	71.09	67.39	202.20	210.27
	70	23.34	23.13	0.509	0.474	966.20	876.04	73.76	70.03	193.37	203.63
Giza 11	30	14.64	14.05	0.270	0.246	502.62	457.83	62.28	58.23	144.87	148.90
	50	15.38	14.90	0.335	0.313	623.74	585.60	65.67	61.96	139.23	142.77
	70	16.06	15.64	0.385	0.357	715.02	667.42	68.13	64.02	134.43	138.97
Giza 12	30	15.07	14.81	0.287	0.271	527.55	496.73	64.57	61.92	152.63	156.90
	50	15.85	15.44	0.360	0.338	662.17	624.98	68.53	65.82	146.93	152.70
	70	16.64	16.23	0.423	0.387	777.04	713.19	70.18	67.64	141.47	144.90
L.S.D. at 5 %		**1.78**	**1.71**	**0.045**	**0.042**	**97.98**	**90.38**	**2.03**	**1.70**	**7.26**	**9.96**

Table 15. Mean values of fiber yield and its related traits of flax as affected by interaction between flax cultivars and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	Plant density (seeds/m^2)	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Fiber fineness (Nm)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	1500	21.14	20.70	0.449	0.428	640.09	587.96	62.84	60.46	177.83	185.53
	2000	22.97	22.60	0.441	0.404	835.02	768.87	68.96	66.46	202.83	215.17
	2500	23.52	23.44	0.417	0.391	970.51	903.84	79.74	75.52	226.57	231.83
Giza 11	1500	14.23	13.66	0.353	0.320	498.30	451.65	57.86	53.38	129.70	134.37
	2000	15.62	15.00	0.336	0.311	633.14	587.00	63.86	60.45	141.23	144.87
	2500	16.23	15.93	0.301	0.285	709.93	672.20	74.36	70.38	147.60	151.40
Giza 12	1500	14.99	14.52	0.388	0.354	543.85	495.58	60.29	57.71	136.63	143.03
	2000	15.98	15.59	0.362	0.338	675.86	630.43	66.93	63.95	148.93	153.77
	2500	16.59	16.37	0.320	0.304	747.04	708.89	76.06	73.72	155.47	157.70
L.S.D. at 5 %		**1.65**	**1.61**	**0.036**	**0.031**	**93.86**	**84.40**	**1.97**	**1.61**	**7.12**	**6.70**

6) Effect of interaction between nitrogen fertilizer rate and plant densities treatments:

Results recorded in **Table 16** indicate that interaction between nitrogen fertilizer rates and plant densities treatments in both seasons has significant effect on fiber yield/plant, fiber yield/fed, fiber length and fiber fineness of flax, while, total fiber percentage was not significantly affected by interaction between flax cultivars and plant densities treatments in both seasons. Flax planting with soil fertilized by 70 kg N/fed at 2500 seeds/m^2 gave the highest fiber yield/fed (960.57 and 886.00 kg) and longest fiber length (79.91 and 75.86 cm) in both seasons respectively. On the other hand, the lowest fiber yield/fed (456.16 and 421.50 kg) and shortest fiber length (56.59 and 53.85 cm) in two respective seasons were obtained from applying 30 kg N/fed at 1500 seeds/m^2. Flax planting when received 70 kg N/fed at 1500 seeds/m^2 gave the heaviest fiber yield/plant (0.464 and 0.429 g) as well as gave the coarser fiber with fiber fineness (140.83 and 147.87 Nm in the respective two seasons). On the other hand, the lightest fiber yield/plant (0.280 and 0.261 g) as well as the softness fiber fineness (182.77 and 185.83 Nm) in both seasons respectively were obtained from applying 30 kg N/fed at plant density of 2500 seeds/m^2. Similar results were reported by **Omar and Ash-Shormillesy 2006; Ahmed 2010 and El-Borhamy 2016.**

7) Effect of interaction between flax cultivars, nitrogen fertilizer rate and plant densities treatments:

Results in **Table 17** revealed that interaction between flax cultivars X nitrogen fertilizer rates X plant densities treatments had significant effect on fiber yield/plant, fiber yield/fed, fiber length and fiber fineness of flax, while, total fiber percentage was not significantly affected by interaction in both seasons. The maximum fiber yield/plant (0.518 and 0.509 g in two respective seasons) was obtained from Sakha 3 cultivar when soil fertilized by 70 kg N/fed and using plant density of 1500 seeds/m^2. On the other hand, the minimum fiber yield/plant (0.244 and 0.227 g) in both seasons respectively was produced from Giza 11 cultivar when received 30 kg N/fed at plant density of

2500 seeds/m^2. The heaviest fiber yield/fed (1164.79 and 1051.40 kg) and the longest fiber length (83.93 and 78.87 cm) in both seasons respectively were obtained by Sakha 3 cultivar with 70 kg N/fed at plant density of 2500 seeds/m^2. Whereas, Giza 11 cultivar when received 30 kg N/fed at plant density of 1500 seeds/m^2 gave the lowest fiber yield/fed (413.14 and 376.81 kg) and the shortest fiber length (54.69 and 50.11 cm) in both seasons respectively. The most effective interaction treatment for produced the softness fiber fineness was Sakha 3 cultivar with 30 kg N/fed at plant density of 2500 seeds/m^2 (233.60 and 239.70 Nm) during both seasons respectively. Meanwhile, Giza 11 cultivar under soil fertilized by 70 kg N/fed with plant density of 1500 seeds/m^2 recorded the coarser fiber with fiber fineness 123.80 and 129.70 Nm during both seasons respectively. These results agree with those obtained by **Omar and Ash-Shormillesy 2006; Ahmed 2010 and El-Borhamy 2016.**

Table 16. Mean values of fiber yield and its related traits of flax as affected by interaction between nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Nitrogen rate (kg N/fed)	Plant density (seeds/m^2)	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Fiber fineness (Nm)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
30	**1500**	15.97	15.57	0.325	0.302	456.16	421.50	154.17	53.85	154.17	160.40
	2000	17.37	16.86	0.309	0.283	574.99	524.51	172.23	61.19	172.23	178.20
	2500	17.86	17.63	0.280	0.261	650.21	603.51	182.77	70.12	182.77	185.83
50	**1500**	16.80	16.18	0.402	0.371	568.00	515.52	149.17	57.87	149.17	154.67
	2000	18.30	17.86	0.386	0.359	729.43	689.30	163.27	63.66	163.27	170.60
	2500	18.93	18.71	0.349	0.341	816.70	795.43	175.93	73.63	175.93	180.47
70	**1500**	17.59	17.13	0.464	0.429	658.09	598.18	140.83	59.83	140.83	147.87
	2000	18.90	18.47	0.445	0.411	839.61	772.48	157.50	66.01	157.50	165.00
	2500	19.55	19.40	0.408	0.378	960.57	886.00	170.93	75.86	170.93	174.63
L.S.D. at 5 %		**N.S.**	**N.S.**	**0.036**	**0.031**	**93.86**	**84.40**	**1.97**	**1.61**	**7.12**	**6.70**

Table 17. Mean values of fiber yield and its related traits of flax as affected by interaction between flax cultivar, nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

Flax cultivar	N rate	Plant density	Total fiber (%)		Fiber yield/plant (g)		Fiber yield/fed (kg)		Fiber length (cm)		Fiber fineness (Nm)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Sakha 3	30	**1500**	20.25	19.58	0.369	0.343	517.34	473.05	59.00	57.59	185.70	191.60
		2000	21.99	21.77	0.360	0.331	662.67	603.95	65.85	64.70	215.70	224.60
		2500	22.24	22.23	0.339	0.314	773.56	707.86	75.25	72.76	233.60	239.70
	50	**1500**	21.16	20.53	0.459	0.431	655.85	589.47	63.93	60.85	180.60	186.70
		2000	23.25	22.85	0.447	0.417	855.66	827.28	69.30	66.39	200.30	213.50
		2500	23.98	23.85	0.419	0.410	973.17	952.27	80.04	74.92	225.70	230.60
	70	**1500**	22.01	21.99	0.518	0.509	747.07	701.37	65.60	62.94	167.20	178.30
		2000	23.66	23.17	0.517	0.463	986.74	875.36	71.74	68.29	192.50	207.40
		2500	24.34	24.23	0.492	0.449	1164.79	1051.40	83.93	78.87	220.40	225.20
Giza 11	30	**1500**	13.58	13.11	0.292	0.267	413.14	376.81	54.69	50.11	135.60	139.80
		2000	14.89	13.93	0.275	0.244	518.66	460.77	61.64	57.53	146.70	151.30
		2500	15.44	15.10	0.244	0.227	576.07	535.90	70.51	67.05	152.30	155.60
	50	**1500**	14.22	13.65	0.356	0.327	502.89	461.30	58.19	54.10	129.70	133.60
		2000	15.67	15.19	0.343	0.318	646.74	598.56	63.67	60.82	140.20	143.60
		2500	16.25	15.87	0.306	0.295	721.58	696.93	75.15	70.95	147.80	151.10
	70	**1500**	14.89	14.22	0.411	0.366	578.89	516.83	60.69	55.93	123.80	129.70
		2000	16.31	15.88	0.390	0.373	734.03	701.66	66.26	63.01	136.80	139.70
		2500	16.99	16.82	0.353	0.333	832.13	783.77	77.43	73.13	142.70	147.50
Giza 12	30	**1500**	14.08	14.01	0.313	0.296	437.99	414.63	56.07	53.86	141.20	149.80
		2000	15.24	14.87	0.291	0.273	543.65	508.81	64.80	61.34	154.30	158.70
		2500	15.89	15.55	0.258	0.243	601.00	566.76	72.85	70.55	162.40	162.20
	50	**1500**	15.02	14.36	0.389	0.354	545.26	495.78	61.14	58.66	137.20	143.70
		2000	15.99	15.55	0.367	0.344	685.89	642.06	67.48	63.78	149.30	154.70
		2500	16.55	16.41	0.324	0.316	755.34	737.10	76.98	75.01	154.30	159.70
	70	**1500**	15.88	15.18	0.463	0.412	648.30	576.35	63.67	60.62	131.50	135.60
		2000	16.72	16.35	0.428	0.397	798.05	740.41	68.50	66.72	143.20	147.90
		2500	17.33	17.16	0.379	0.353	884.78	822.82	78.36	75.59	149.70	151.20
L.S.D. at 5 %			**N.S.**	**N.S.**	**0.063**	**0.054**	**162.57**	**146.19**	**3.42**	**2.79**	**12.33**	**11.61**

C- Anatomical manifestations:

Mean values of different tissues area per cross section at the middle region of stems and fiber index estimates for three flax cultivars as affected by nitrogen fertilizer rates and plant densities treatments during the second season are presented in **Table 18.** Data illustrated an increase in each of total cross section, cortex, fiber, xylem areas and fiber index per plant in all flax cultivars under study (Sakha 3, Giza 11 and Giza 12) as affected by fertilized flax plants with 70 kg N/fed and plant density at 1500 seeds/m^2. The respective values of these previous characters for Sakha 3 cultivar were 4.91, 0.89, 0.83, 1.57 mm^2 and 581.25 mm^3, respectively. Meanwhile, Giza 11 cultivar recorded 7.07, 1.22, 0.77, 3.31 mm^2 and 512.20 mm^3. In addition to 6.38, 1.02, 0.70, 3.06 mm^2 and 470.96 mm^3 for Giza 12 cultivar in the same arrangement with mentioned before. But the lowest estimates for these traits which above mentioned were obtained by added 30 kg N/fed and plant density at 2500 seeds/m^2 for the three flax cultivars. Pith area per cross section was slightly greater by using 30 kg N/fed and highest plant density (2500 seeds/m^2). It must be mentioned, that Sakha 3 cultivar achieved highest fiber area per cross section when compared with the other two ones (Giza 11 and Giza 12), meanwhile the latter two cultivars recorded more xylem area per cross section. Added 50 kg N/fed and plant density of 2000 seeds/m^2 gave intermediate estimates between either 30 kg N/fed and 2500 seeds/m^2 or 70 kg N/fed and 1500 seeds/m^2. Slight variation between the three flax cultivars under 30 kg N/fed with plant density of 2500 seeds/m^2 and 70 kg N/fed with plant density of 1500 seeds/m^2 on the different tissues area cross sections are shown in **Figs 1 to 6.** The present findings are in accordance with those recorded by **El-Shimy *et al*. 1993; El-Nagdy *et al*. 2010; El-Gedwy *et al*. 2018 and El-Shimy *et al*. 2019.**

Percentage of different tissue areas concerning its corresponding total cross section area for three flax cultivars as affected by nitrogen fertilizer rates and plant densities treatments during the second season are presented in **Table 19**. Results indicated that the treatment of 30 kg N/fed and plant density by 2500 seeds/m^2 achieved highest percentages of fiber and pith % in all three flax cultivars. It means that more plant density per unit area caused an increment in fiber as resulted from tallest technical stem length and relatively thinner flax plants, consequently more fiber yield with fineness and more pith area which had observed in fiber flax type characteristics. In the same time, cortex and xylem % took opposite trend, that the treatment of 70 kg N/fed and plant density of 1500 seeds/m^2 which recorded maximum cortex and xylem % in Sakha 3, Giza 11 and Giza 12. The present findings are in accordance with those recorded by **El-Shimy *et al*. 1993; El-Nagdy *et al*. 2010; El-Gedwy *et al*. 2018 and El-Shimy *et al*. 2019.**

Table 18: Mean values of different tissues area per cross section at the middle region of stems and fiber index estimates for three flax cultivars as affected by nitrogen fertilizer rates and plant densities treatments during 2019/2020 season.

Flax cultivar	N rate (kg/fed)	Plant density (seeds/m^2)	Total cross section area (mm^2)	Cortex area (mm^2)	Fiber area (mm^2)	Xylem (mm^2)	Pith (mm^2)	Fiber index/plant (mm^3)
Sakha 3	**30**	**2500**	4.23	0.63	0.78	1.14	1.68	546.23
	50	**2000**	4.52	0.74	0.80	1.40	1.58	560.24
	70	**1500**	4.91	0.89	0.83	1.57	1.62	581.25
Giza 11	**30**	**2500**	5.38	0.60	0.69	2.31	1.78	458.99
	50	**2000**	6.15	0.93	0.74	2.73	1.75	492.25
	70	**1500**	7.07	1.22	0.77	3.32	1.76	512.20
Giza 12	**30**	**2500**	5.06	0.61	0.62	2.13	1.70	417.14
	50	**2000**	5.34	0.75	0.65	2.28	1.66	437.32
	70	**1500**	6.38	1.02	0.70	3.06	1.60	470.96

Table 19. Percentage of different tissue areas concerning its corresponding total cross section area for three flax cultivars as affected by nitrogen fertilizer rates and plant densities treatments during 2019/2020 season.

Flax Cultivar	N rate (kg/fed)	Plant density (seeds/m^2)	Cortex %	Fiber %	Xylem %	Pith %
Sakha 3	**30**	**2500**	14.89	18.44	26.95	39.72
	50	**2000**	16.37	17.70	30.97	34.96
	70	**1500**	18.13	16.90	31.98	32.99
Giza 11	**30**	**2500**	11.15	12.83	42.94	33.09
	50	**2000**	15.12	12.03	44.39	28.46
	70	**1500**	17.26	10.89	46.96	24.89
Giza 12	**30**	**2500**	12.06	12.25	42.09	33.60
	50	**2000**	14.04	12.17	42.70	31.09
	70	**1500**	15.99	10.97	47.96	25.08

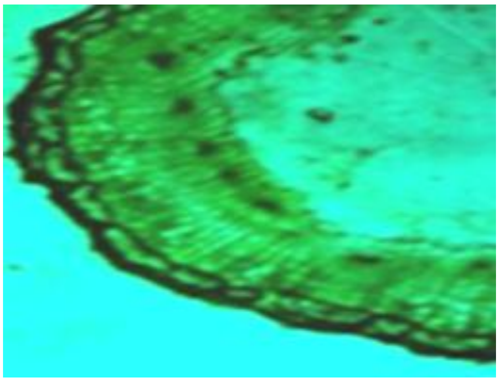

Fig 1: Cross section in the middle region at full maturity of Sakha 3 *cv*. with soil fertilized by 30 kg N/fed and plant density of 2500 seeds/m^2

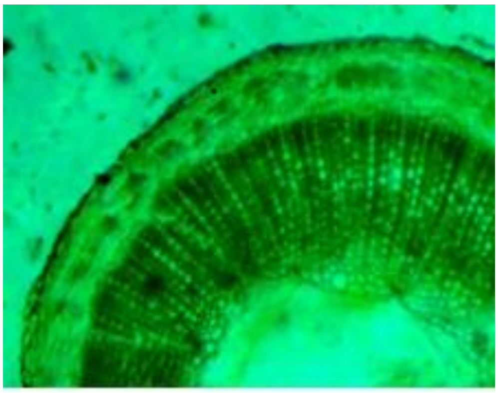

Fig 2: Cross section in the middle region at full maturity of Sakha 3 *cv*. with soil fertilized by 70 kg N/fed and plant density of 1500 seeds/m^2

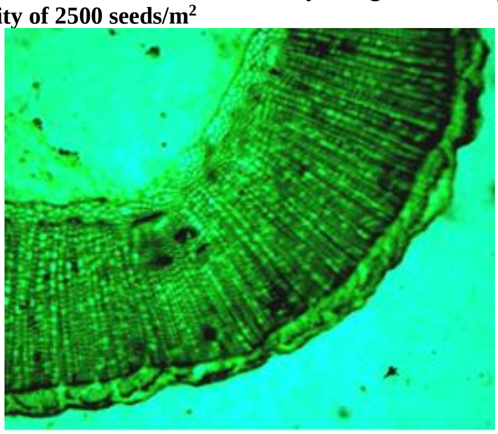

Fig 3: Cross section in the middle region at full maturity of Giza 11 *cv*. with soil fertilized by 30 kg N/fed and plant density of 2500 seeds/m^2

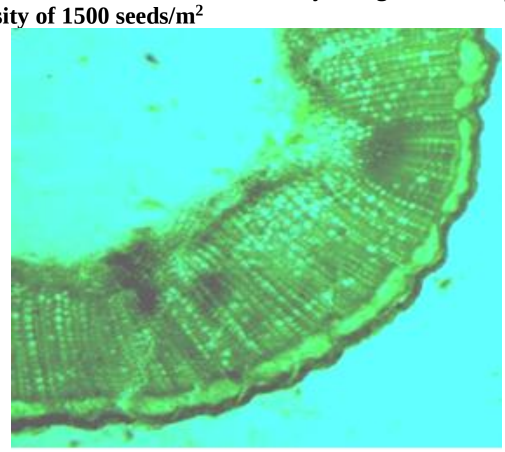

Fig 4: Cross section in the middle region at full maturity of Giza 11 *cv*. with soil fertilized by 70 kg N/fed and plant density of 1500 seeds/m^2

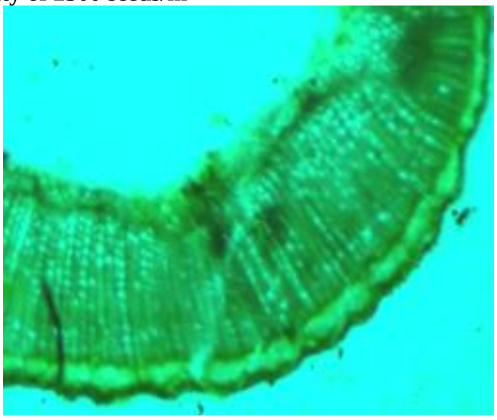

Fig 5: Cross section in the middle region at full maturity of Giza 12 *cv*. with soil fertilized by 30 kg N/fed and plant density of 2500 seeds/m^2

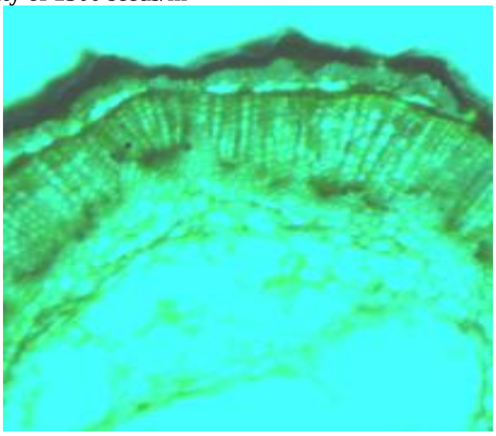

Fig 6: Cross section in the middle region at full maturity of Giza 12 cv. with soil fertilized by 70 kg N/fed and plant density of 1500 seeds/m^2

Conclusion:

From the obtained results of this study it could be concluded that Sakha 3 cultivar and fertilizing by 70 kg N/fed with plant density of 2500 seeds/m^2 achieved maximum fiber yield/fed and quality.

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تأثير الكثافة النباتية و معدلات السماد النيتروجيني على محصول القش، الألياف و الصفات التشريحية لبعض أصناف الكتان

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أجريت تجربتان حقليتان في مزرعة محطة البحوث الزراعية بالجميزة ـ محافظة الغربية ـ مركز البحوث الزراعية ـ مصر. خلال الموسمين الشتويين 2019/2018 و 2020/2019، لدراسة تأثير ثلاثة معدلات من السماد النيتروجيني (30 ، 50 و 70 كجم نيتروجين/فدان) و ثلاثة كثافات نباتية (1500، 2000 و 2500 بذرة/م^2) على محصول القش و الألياف و الصفات المرتبطة بهما و كذلك دراسة بعض المظاهر التشريحية في منتصف الساق الرئيسي لثلاثة أصناف من الكتان هي سخا 3، جيزة 11 و جيزة 12. و كان التصميم التجريبي المستخدم هو القطع المنشقة مرتان في أربع مكررات ووضعت الأصناف في القطع الرئيسية بينما تم توزيع معدلات السماد النيتروجيني في القطع الشقية الأولى والكثافات النباتية في القطع الشقية الثانية وكانت مساحة القطعة الشقية الثانية 9 م^2 .

الإختلافات بين أصناف الكتان تحت الدراسة كانت معنوية في جميع الصفات المدروسة لمحصول القش و الألياف و الصفات المرتبطة بهما خلال موسمي الزراعة. أفضل متوسط قيم لصفات إرتفاع النبات الكلي، الطول الفعال، النسبة الكلية للألياف، محصول الألياف/نبات، محصول الألياف/فدان، طول الألياف و نعومة الألياف تم الحصول عليهما من نباتات صنف الكتان سخا 3 خلال موسمي الدراسة. بينما تفوق صنف الكتان جيزة 12 في متوسط قيم صفات عدد الأفرع القاعدية/نبات، محصول القش/نبات و محصول القش/فدان خلال موسمي الدراسة. بينما زراعة صنف الكتان جيزة 11 أنتج معنوياً أغلظ سيقان للكتان خلال موسمي الدراسة.

إزدادت معنوياً متوسط قيم معظم الصفات المدروسة لمحصول القش و الألياف و الصفات المرتبطة بهما بزيادة معدلات السماد النيتروجيني من 30 إلى 70 كجم نيتروجين/فدان في كلا الموسمين على العكس إنخفضت متوسط قيم صفة نعومة الألياف مع زيادة مستوى السماد النيتروجيني في كلا الموسمين. بينما لم تتأثر متوسط قيم صفة عدد الأفرع القاعدية/نبات بمعدلات السماد النيتروجيني تحت الدراسة خلال موسمي الزراعة.

زيادة الكثافة النباتية لنباتات الكتان من 1500 إلى2500 بذرة/م^2 أدت إلى زيادة معنوية في متوسط قيم صفات إرتفاع النبات الكلي، الطول الفعال، محصول القش/فدان، النسبة الكلية للألياف، محصول الألياف/فدان، طول الألياف و نعومة الألياف على العكس نقص متوسط قيم صفات عدد الأفرع القاعدية/نبات، سمك الساق، محصول القش/نبات و محصول الألياف/نبات خلال موسمي الدراسة.

التفاعلات من الدرجة الأولى بين المعاملات سخا 3 X 70 كجم نيتروجين/فدان، سخا 3 X 2500 بذرة/م^2 و 70 كجم نيتروجين/فدان X 2500 بذرة/م^2 و التفاعل من الدرجة الثانية بين المعاملات سخا 3 X 70 كجم نيتروجين/فدان X 2500 بذرة/م^2 حققت معنويا أعلى متوسط قيم لصفات إرتفاع النبات الكلي، الطول الفعال، محصول الألياف/فدان و طول الألياف مقارنةً بالتفاعلات بين المعاملات الأخري في كلا الموسمين. بينما أعلى متوسط قيم لصفة محصول القش/فدان تم الحصول عليها من التفاعلات من الدرجة الأولى بين المعاملات جيزة 12 X 70 كجم نيتروجين/فدان، جيزة 12 X 2500 بذرة/م^2 و 70 كجم نيتروجين/فدان X 2500 بذرة/م^2 و التفاعل من الدرجة الثانية بين المعاملات جيزة 12 X 70 كجم نيتروجين/فدان X 2500 بذرة/م^2.

أشارت النتائج حدوث زيادة في كل من المقطع العرضي الكلي للساق، مساحة القشرة، مساحة الألياف، مساحة الخشب، دليل الألياف/نبات، النسبة المئوية للقشرة و النسبة المئوية للخشب في جميع الإصناف المنزرعة (سخا 3 ، جيزة 11 و جيزة 12) عند تسميد حقول الكتان بمعدل 70 كجم نيتروجين/فدان و زراعتها بكثافة نباتية 1500 بذرة/م^2.

الخلاصة:

توصي النتائج بزراعة الكتان صنف سخا 3 مع التسميد النيتروجيني بمعدل 70 كجم نيتروجين/فدان عند كثافة نباتية 2500 بذرة/م^2 حيث عظمت إنتاجية محصول الألياف بوحدة المساحة.