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# Seed Yield and Quality Traits of Some Flax Cultivars as Influenced by Nitrogen Fertilizer Rates and Plant Density

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## Abstract

Two field experiments were conducted on the Experimental Farm at El-Gemmeiza Research Station, Gharbia Governorate, Agricultural Research Center, Egypt, during two successive winter seasons of 2018/2019 and 2019/2020 to investigate the effect of three nitrogen fertilizer rates (30, 50 and 70 kg N/fed) and three plant densities (1500, 2000 and 2500 seeds/$m^2$) on seed and oil yield and its related traits of three flax cultivars (Sakha 3 Giza 11 and Giza 12). 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 $m^2$. Giza 11 cultivar significantly recorded the maximum mean values in No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed index, seed yield/plant, seed yield/fed, harvest index, oil yield/plant and oil yield/fed in two seasons. Meanwhile, the maximum mean values of seed oil content in both seasons were obtained from Giza 12 cultivar. While, flax cultivar of Sakha 3 significantly gave the maximum upper branching zone length and No. of seeds/capsule in both seasons. All seed and oil yield and its related traits of flax were significantly increased with increasing nitrogen fertilizer rates from 30 to 50 and 70 kg N/fed under study in two seasons. Flax plants growing at lowest plant density (1500 seeds/$m^2$) markedly gave the greatest mean values of upper branching zone length, No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed yield/plant, harvest index and oil yield/plant in both seasons. Meanwhile, the maximum mean values of seed yield/fed and oil yield/fed which were obtained from flax planting at highest plant density (2500 seeds/$m^2$) in both seasons. The first order interactions between treatments Giza 11 X 70 kg N/fed, Giza 11 X 1500 seeds/$m^2$ and 70 kg N/fed X 1500 seeds/$m^2$ as well as the second order interaction between treatments Giza 11 X 70 kg N/fed X 1500 seeds/$m^2$ were significantly recorded the greatest seed and oil yield of individual plants as compared with the others interactions in both seasons. While, the maximum mean values of seed and oil yield/fed were recorded from the first order interactions between treatments Giza 11 X 70 kg N/fed, Giza 11 X 2500 seeds/$m^2$ and 70 kg N/fed X 2500 seeds/$m^2$ as well as the second order interaction between treatments Giza 11 X 70 kg N/fed X 2500 seeds/$m^2$. It could be concluded that flax planting cultivar of Giza 11 and fertilizing by 70 kg N/fed with plant density of 2500 seeds/$m^2$ to maximizing seed and oil yield/fed.

**Keywords:** flax cultivars, Sakha 3, Giza 11, Giza 12, Nitrogen fertilizer, plant densities, seed yield and oil yield.

## 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 fiber and seeds of flax. 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 they found that significant differences among the flax cultivars in seed and oil yield and its related traits **(Khan *et al.* 2005; Zimmermann *et al.* 2006; Kocjan-Ačko and Trdan 2008; Lafond *et al.* 2008; Ahmed 2010; Irvine *et al.* 2010; Laza and Pop 2012; Kariuki *et al.* 2014; Abd Eldaiem and El-Borhamy 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; Erdoğdu *et al.* 2018; Leilah *et al.* 2018; Sarkees and Mahmood 2018; Osmari *et al.* 2019 and Emam 2020).**

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 as **Zimmermann *et al.* 2006; Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Shaker *et al.* 2012; Kariuki *et al.* 2014; Abd Eldaiem and El-**

**Borhamy 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; El-Gedwy *et al.* 2018; Leilah *et al.* 2018; Taddese and Tenaye 2018 and Osmari *et al.* 2019** reported that increasing nitrogen fertilizer rates caused significant increase in all seed and oil traits of flax.

The effect of plant density on seed and oil yield as well as their quality was studied by many investigators as **Khan *et al.* 2005; Kocjan-Ačko and Trdan 2008; Lafond *et al.* 2008; Ahmed 2010; Irvine *et al.* 2010; Laza and Pop 2012; Shaker *et al.* 2012; Andruszczak *et al.* 2015; El-Borhamy 2016; Erdoğdu *et al.* 2018; Sarkees and Mahmood 2018; Ganvit *et al.* 2019 and Teshome *et al.* 2020**, who found significant increase in mean values of seed yield/fed and oil yield/fed but significant decreased in mean values of upper branching zone length, No. of upper branches/plant, No. of capsules/plant, No. of seeds/capsule, No. of seeds/plant, seed yield/plant, seed index, harvest index, seed oil content and oil yield/plant with increasing plant density.

The aim of this investigation was designed to study the effect of nitrogen fertilizer rates and plant densities on seed and oil yield and its components of flax cultivars in farm at El-Gemmeiza Research Station, Gharbia Governorate, Egypt.

## Materials and Methods:

Two field experiments were carried out at the Farm at El-Gemmeiza Research Station, Gharbia Governorate, Agricultural Research Center, Egypt, during two successive winter seasons of 2018/2019 and 2019/2020. The aim of this study was to investigate the performance of three flax cultivars, *i.e.* Sakha 3, Giza 11 and Giza 12 to three nitrogen fertilizers rates, *i.e.* 30, 50 and 70 kg N/fed and three plant population densities (1500, 2000 and 2500 seeds/$m^2$) on seed and oil yield and its components.

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.

**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 (Particle size distribution)** | | |
| 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** | |

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 1$^{th}$ and 11$^{th}$ 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 other recommended agronomic practices of growing flax were applied in the manner prevailing in the region were practiced.

**Studied traits:**

At maturity, about 150 days from sowing date, ten guarded plants were taken randomly from each sub-sub plot for recording seed plant traits. Biological yield/fed (kg) and seed yield/fed (kg) were estimated according to yield from three meter square of each sub-sub plot. The recorded traits included: upper branching zone length (cm), No. of upper branches/plant, No. of capsules/plant, No. of seeds/capsule, No. of seeds/plant, seed index {1000-seed weight} (g), seed yield/plant (g), seed yield/fed (kg), biological yield/fed (kg), harvest index (%) it was calculated from dividing (seed yield/biological yield) X 100, oil seed content (%) it was determined as described by the **(A. O. A. C., 1990)** methods, using petroleum ether (40-60 °C) in Soxhlet apparatus, oil yield/plant (g) it was calculated by multiplying seed yield/plant (g) X oil % as well as oil yield/fed (kg) it was calculated by multiplying seed yield/fed (kg) X oil %.

**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:

**1- Effect of flax cultivars:**

The differences among the three flax cultivars under study in mean values of all seed and oil yield and its related traits of flax under study were significant affected in both seasons, as shown in **Table 4**. The differences in mean values of upper branching zone length, No. of upper branches/plant, No. of seeds/capsule, seed index, seed oil content, oil yield/plant and oil yield/fed between Giza 12 and Giza 11 were not significant in both seasons. Sakha 3 cultivar significantly recorded the maximum upper branching zone length and No. of seeds/capsule in both seasons. Sakha 3 cultivar significantly increased the mean values of upper branching zone length by 20.90 and 30.19 % in the first season, and by 29.12 and 36.06 % in the second season, as compared to mean values of upper branching zone length of Giza 12 and Giza 11 cultivars, respectively. Giza 11 cultivar significantly gave the maximum mean values in No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed index, seed yield/plant, seed yield/fed, harvest index, oil yield/plant and oil yield/fed in two seasons. The superiority ratios in the first season between flax cultivar of Giza 11 and each of Giza 12 and Sakha 3 were 11.81 and 100.21 % for No. of capsules/plant; 15.56 and 83.72 % for No. of seeds/plant; 20.15 and 218.13 % for seed yield/plant; 5.03 and 73.94 % for seed yield/fed in addition to 7.25 and 48.56 % for harvest index, respectively. The excess ratios in the second season when flax planting cultivar of Giza 11 over each of Giza 12 and Sakha 3 were 10.42 and 119.29 % for No. of capsules/plant; 14.72 and 101.20 % for No. of seeds/plant; 19.35 and 242.69 % for seed yield/plant; 10.07 and 85.79 % for seed yield/fed in addition to 11.54 and 54.48 % for harvest index, respectively. also, in the rest traits, the superiority ratios in the first season between flax cultivars of Giza 12 and Giza 11 over Sakha 3 were 50.83 and 53.56 % for No. of upper branches/plant; 66.79 and 73.48 % for seed index; 201.19 and 257.71 % for oil yield/plant in addition to 87.87 and 95.10 % for oil yield/fed, respectively. The superiority ratios in the second season when planting Giza 12 and Giza 11 cultivars over Sakha 3 cultivar were 50.09 and 52.56 % for No. of upper branches/plant; 63.53 and 70.22 % for seed index; 217.99 and 276.72 % for oil yield/plant in addition to 87.81 and 105.11 % for oil yield/fed, respectively. The maximum mean values of seed oil content in both seasons were obtained from Giza 12 cultivar. Giza 11 and Giza 12 cultivars significantly increased mean values of seed oil content by 12.36 and 13.65 % in the first season, respectively corresponding to 10.44 and 11.29 % in the second season, respectively, over mean values of seed oil content of Sakha 3 flax cultivar. These differences may be due to the genetic differences between flax cultivar of Sakha 3 (fiber flax type) and flax cultivars of Giza 11 and Giza 12 (dual purpose type). Also, It could be concluded that flax cultivar of Giza 11 surpassed the other flax cultivars to increase mean values of seed yield/fed may be due to more likely attributed to the increases in mean values in No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed index and seed yield/plant. These results are in agreement with those obtained by **Khan *et al.* 2005; Zimmermann *et al.* 2006; Kocjan-Ačko and Trdan 2008; Lafond *et al.* 2008; Ahmed 2010; Irvine *et al.* 2010; Laza and Pop 2012; Kariuki *et al.* 2014; Abd Eldaiem and El-Borhamy 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; Erdoğdu *et al.* 2018; Leilah *et al.* 2018; Sarkees and Mahmood 2018; Osmari *et al.* 2019 and Emam 2020,** who reported marked differences in mean values of seed and oil yield and its related traits among flax cultivars.

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

| Flax cultivar | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| **Sakha 3** | 26.09 | 24.30 | 36.61 | 32.44 | 14.38 | 12.03 | 8.21 | 7.78 | 118.54 | 93.92 | 5.637 | 5.440 |
| **Giza 11** | 20.04 | 17.86 | 56.22 | 49.49 | 28.79 | 26.38 | 7.54 | 7.14 | 217.78 | 188.97 | 9.779 | 9.260 |
| **Giza 12** | 21.58 | 18.82 | 55.22 | 48.69 | 25.75 | 23.89 | 7.29 | 6.87 | 188.45 | 164.72 | 9.402 | 8.896 |
| **L.S.D. at 5 %** | **2.23** | **1.89** | **4.99** | **4.11** | **2.55** | **2.23** | **0.33** | **0.31** | **14.56** | **11.23** | 0.405 | 0.369 |
| | **Seed yield/plant (g)** | | **Seed yield/fed (kg)** | | **Harvest index (%)** | | **Seed oil content (%)** | | **Oil yield/plant (g)** | | **Oil yield/fed (kg)** | |
| **Sakha 3** | 0.673 | 0.513 | 430.03 | 382.22 | 10.75 | 10.26 | 37.37 | 36.49 | 0.253 | 0.189 | 161.12 | 139.76 |
| **Giza 11** | 2.141 | 1.758 | 748.00 | 710.14 | 15.97 | 15.85 | 41.99 | 40.30 | 0.905 | 0.712 | 314.34 | 286.66 |
| **Giza 12** | 1.782 | 1.473 | 712.16 | 645.17 | 14.89 | 14.21 | 42.47 | 40.61 | 0.762 | 0.601 | 302.70 | 262.49 |
| **L.S.D. at 5 %** | **0.111** | **0.098** | **31.87** | **29.05** | **0.42** | **0.38** | **1.05** | **0.98** | **0.145** | **0.128** | **27.25** | **25.88** |

**2- Effect of nitrogen fertilizer rates:**

Results in **Table 5,** indicated that all seed and oil yield and its related traits of flax were significantly increased with increasing nitrogen fertilizer rates from 30 to 50 and 70 kg N/fed, except No. of seeds/capsule, seed index and harvest index of flax were not significantly affected by raising nitrogen fertilizer rates in both seasons. Flax planting when received 70 kg N/fed significantly gave the maximum mean values of all flax seed and oil yield and its related traits in both seasons. The superiority ratios in the first season between 70 kg N/fed and each of 50 and 30 kg N/fed were 5.83 and 10.81% for upper branching zone length; 8.59 and 18.95 % for No. of upper branches/plant; 9.09 and 28.25% for No. of capsules/plant; 11.78 and 35.83 % for No. of seeds/plant; 13.47 and 42.24 % for seed yield/plant; 9.23 and 26.50 % for seed yield/fed; 3.53 and 6.66 % for seed oil content; 17.69 and 51.49 % for oil yield/plant in addition to 13.11 and 34.42 % for oil yield/fed, 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 5.42 and 11.11 % for upper branching zone length; 7.02 and 18.22 % for No. of upper branches/plant; 11.52 and 27.43 % for No. of capsules/plant; 14.10 and 34.36 % for No. of seeds/plant; 16.10 and 41.18 % for seed yield/plant; 11.05 and 28.82 % for seed yield/fed; 3.08 and 7.18 % for seed oil content; 19.44 and 51.64 % for oil yield/plant in addition to 14.29 and 37.73 % for oil yield/fed, respectively. The increase in seed and oil yield and its attributes because of increasing nitrogen fertilizer rates up to 70 kg N/fed can be easily ascribed to the role of nitrogen in activating growth of plants, consequently enhancement seed and oil yield and its attributes. It could be concluded that nitrogen fertilizer application encouraged the seeds filling of flax plants leading to a greater seed index and increasing seed oil content. It was clear that the increases in oil yield/fed may be due to the increases in seed yield/plant, seed yield/fed and seed oil content of flax resulting from a good supply of adequate nitrogen rate. These results are in compatible with those found by **Zimmermann *et al*. 2006; Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Shaker *et al.* 2012; Kariuki *et al.* 2014; Abd Eldaiem and El-Borhamy 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; El-Gedwy *et al.* 2018; Leilah *et al*. 2018 and Osmari *et al*. 2019.**

**Table 5.** Mean values of seed and oil 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) | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| **30** | 21.46 | 19.27 | 45.07 | 39.74 | 19.93 | 18.23 | 7.46 | 7.07 | 146.85 | 127.12 | 8.029 | 7.627 |
| **50** | 22.47 | 20.31 | 49.37 | 43.90 | 23.43 | 20.83 | 7.70 | 7.28 | 178.45 | 149.69 | 8.325 | 7.909 |
| **70** | 23.78 | 21.41 | 53.61 | 46.98 | 25.56 | 23.23 | 7.88 | 7.43 | 199.47 | 170.80 | 8.465 | 8.059 |
| **L.S.D. at 5 %** | **1.88** | **1.53** | **3.18** | **2.95** | **1.98** | **1.89** | **N.S.** | **N.S.** | **9.85** | **8.59** | **N.S.** | **N.S.** |
| | **Seed yield/plant (g)** | | **Seed yield/fed (kg)** | | **Harvest index (%)** | | **Seed oil content (%)** | | **Oil yield/plant (g)** | | **Oil yield/fed (kg)** | |
| **30** | 1.250 | 1.032 | 552.19 | 503.89 | 14.10 | 13.64 | 39.34 | 37.73 | 0.505 | 0.397 | 220.28 | 192.31 |
| **50** | 1.567 | 1.255 | 639.49 | 584.53 | 13.87 | 13.19 | 40.53 | 39.23 | 0.650 | 0.504 | 261.78 | 231.74 |
| **70** | 1.778 | 1.457 | 698.51 | 649.11 | 13.64 | 13.50 | 41.96 | 40.44 | 0.765 | 0.602 | 296.11 | 264.86 |
| **L.S.D. at 5 %** | 0.073 | 0.069 | 26.55 | 24.34 | N.S. | N.S. | 0.92 | 0.85 | 0.108 | 0.095 | 21.98 | 17.32 |

**3- Effect of plant densities treatments:**

Mean values of all seed and oil yield and its related traits under study were significantly affected by plant densities treatments during two seasons. Meanwhile, mean values in No. of seeds/capsule, seed index and seed oil content were not significantly affected by plant densities under study during both seasons, as shown in **Table 6.** Growing flax at plant density with 1500 seeds/$m^2$ markedly gave the greatest mean values of upper branching zone length, No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed yield/plant, harvest index and oil yield/plant in both seasons. On the other hand, the lowest mean values of previous traits which were obtained from flax planting with plant density of 2500 seeds/$m^2$ in two seasons. The superiority ratios in the first season between growing flax with plant density of 1500 seeds/$m^2$ and each of 2000 and 2500 seeds/$m^2$ were 9.17 and 24.09 % for upper branching zone length; 13.02 and 33.17 % for No. of upper branches/plant; 10.95 and 33.97 % for No. of capsules/plant; 12.00 and 38.14 % for No. of seeds/plant; 14.79 and 46.90 % for seed yield/plant; 6.28 and 8.83 % for harvest index in addition to 18.74 and 55.85 % for oil yield/plant, respectively. The increase ratios in the second season when sowing plant at 1500 seeds/$m^2$ over each of 2000 and 2500 seeds/$m^2$ were 9.93 and 26.63 % for upper branching zone length; 12.82 and 32.59 % for No. of upper branches/plant; 15.94 and 30.71 % for No. of capsules/plant; 18.03 and 34.82 % for No. of seeds/plant; 20.98 and 40.84 % for seed yield/plant; 5.64 and 8.33 % for harvest index in addition to 22.90 and 45.87 % for oil yield/plant, respectively. Such increases in mean values of seed yield/plant at planting density of 1500 seeds/$m^2$ could be due to the increases in mean values of upper branching zone length, No. of upper branches/plant, No. of capsules/plant and No. of seeds/plant. This trend could be explained on the fact that in case of low density resulted in low competition between flax plants for nutrient elements, soil moisture and sun light, plants would have better opportunity to produce more metabolite contents and positive effect on related traits of seed yield/plant (g). The results agree with those reported by **Khan *et al*. 2005; Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Andruszczak *et al.* 2015; Erdoğdu *et al*. 2018; Sarkees and Mahmood 2018; Ganvit *et al.* 2019 and Teshome *et al*. 2020.** The highest plant density 2500 seeds/$m^2$ caused maximum estimates of mean values of seed yield/fed and oil yield/fed in both seasons, as resulted from more plants were planting in unit area in comparison with the other two plant densities either 1500 or 200 seeds/$m^2$. On the other hand, sowing flax with plant density of 1500 seeds/$m^2$ produced the lowest mean values of seed yield/fed and oil yield/fed in two seasons. In the 2018/2019 season, The superiority ratios between growing flax with plant density of 2500 seeds/$m^2$ and each of 2000 and 1500 seeds/$m^2$ were 5.56 and 15.05 % for seed yield/fed in addition to 3.00 and 8.65 % for oil yield/fed, respectively. The increase ratios in the second season when sowing plant at 2500 seeds/$m^2$ over each of 2000 and 1500 seeds/$m^2$ were 5.76 and 17.31 seed yield/fed in addition to 3.60 and 12.93 % for oil yield/fed, respectively. Such results agree with those reported by **Kocjan-Ačko and Trdan 2008; Irvine *et al*. 2010; Shaker *et al.* 2012; El-Borhamy 2016; Sarkees and Mahmood 2018; Ganvit *et al.* 2019 and Teshome *et al*. 2020.**

**Table 6**. Mean values of seed and oil yield and its related traits of flax as affected by plant densities (seeds/$m^2$) during 2018/2019 ($1^{st}$) and 2019/2020 ($2^{nd}$) seasons.

| Plant density (seeds/$m^2$) | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $1^{st}$ | $2^{nd}$ | $1^{st}$ | $2^{nd}$ | $1^{st}$ | $2^{nd}$ | $1^{st}$ | $2^{nd}$ | $1^{st}$ | $2^{nd}$ | $1^{st}$ | $2^{nd}$ |
| **1500** | 24.88 | 22.59 | 56.17 | 49.47 | 26.03 | 23.71 | 7.78 | 7.39 | 200.54 | 172.89 | 8.506 | 8.042 |
| **2000** | 22.79 | 20.55 | 49.70 | 43.85 | 23.46 | 20.45 | 7.71 | 7.25 | 179.05 | 146.48 | 8.278 | 7.846 |
| **2500** | 20.05 | 17.84 | 42.18 | 37.31 | 19.43 | 18.14 | 7.54 | 7.15 | 145.17 | 128.24 | 8.035 | 7.708 |
| **L.S.D. at 5 %** | **1.59** | **1.46** | **3.02** | **2.88** | **1.83** | **1.74** | **N.S.** | **N.S.** | **8.36** | **7.54** | **N.S.** | **N.S.** |
| | **Seed yield/plant (g)** | | **Seed yield/fed (kg)** | | **Harvest index (%)** | | **Seed oil content (%)** | | **Oil yield/plant (g)** | | **Oil yield/fed (kg)** | |
| **1500** | 1.801 | 1.476 | 583.30 | 529.36 | 14.55 | 14.05 | 41.78 | 39.91 | 0.773 | 0.601 | 247.72 | 213.99 |
| **2000** | 1.569 | 1.220 | 635.78 | 587.17 | 13.69 | 13.30 | 40.54 | 39.14 | 0.651 | 0.489 | 261.30 | 233.27 |
| **2500** | 1.226 | 1.048 | 671.11 | 621.00 | 13.37 | 12.97 | 39.52 | 38.34 | 0.496 | 0.412 | 269.14 | 241.66 |
| **L.S.D. at 5 %** | 0.068 | 0.062 | 23.54 | 21.78 | 0.25 | 0.21 | N.S. | N.S. | 0.098 | 0.094 | 20.14 | 19.75 |

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

Results in **Table 7** showed that significant effect of interaction between flax cultivars and nitrogen fertilizer rates obtained for all seed and oil yield and its related traits of flax in both seasons. While, mean values in No. of seeds/capsule, seed index and seed oil content were not significantly affected by interaction between flax cultivars and nitrogen fertilizer rates in both seasons. Giza 11 cultivar under

soil fertilized by 70 kg N/fed recorded the greatest mean values in No. of upper branches/plant (60.78 and 53.21 upper branches), No. of capsules/plant (31.86 and 29.34 capsules), No. of seeds/plant (247.71 and 215.48 seeds), seed yield/plant (2.477 and 2.040 g), seed yield/fed (818.25 and 782.00 kg), oil yield/plant (1.080 and 0.851 g) and oil yield/fed (355.06 and 325.57 kg) during the first and second seasons, respectively. On the other hand, The lowest mean values in No. of upper branches/plant (33.22 and 29.53 upper branches), No. of capsules/plant (12.09 and 10.28 capsules), No. of seeds/plant (96.97 and 78.24 seeds), seed yield/plant (0.528 and 0.412 g), seed yield/fed (342.50 and 307.67 kg), oil yield/plant (0.191 and 0.146 g) and oil yield/fed (123.44 and 108.40 kg) in both seasons, respectively which were obtained from Sakha 3 cultivar when received 30 kg N/fed. The longest mean values of upper branching zone length (27.29 and 25.48 cm) in both seasons, respectively which were obtained from Sakha 3 cultivar when received 70 kg N/fed. Meanwhile, Giza 11 cultivar when received 30 kg N/fed gave the shortest mean values of upper branching zone length (18.93 and 16.69 cm) in both seasons, respectively. The highest mean values of harvest index which were 16.58 and 16.38 % in the first and second seasons, respectively which were obtained from Giza 11 cultivar when received 30 kg N/fed. Whereas, Sakha 3 cultivar under the same rate of nitrogen (30 kg N/fed) gave the lowest mean values of harvest index (10.25 and 9.94 % in both seasons, respectively). Similar results were also reported by **Zimmermann *et al*. 2006; Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Kariuki *et al.* 2014; Abd Eldaiem and El-Borhamy 2015; Andruszczak *et al.* 2015; El-Borhamy 2016; Leilah *et al*. 2018 and Osmari *et al*. 2019**, whose found variations in mean values of seed and oil yield and its related traits among flax cultivars and nitrogen fertilizer rates interaction.

**Table 7**. Mean values of seed and oil yield and its related traits as of flax 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) | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| | 30 | 24.87 | 23.29 | 33.22 | 29.53 | 12.09 | 10.28 | 8.01 | 7.60 | 96.97 | 78.24 | 5.425 | 5.253 |
| Sakha 3 | 50 | 26.11 | 24.13 | 36.00 | 32.61 | 14.77 | 12.16 | 8.25 | 7.82 | 122.03 | 95.28 | 5.663 | 5.456 |
| | 70 | 27.29 | 25.48 | 40.60 | 35.18 | 16.28 | 13.66 | 8.38 | 7.91 | 136.62 | 108.24 | 5.825 | 5.611 |
| | 30 | 18.93 | 16.69 | 51.63 | 45.27 | 25.41 | 23.45 | 7.27 | 6.94 | 184.90 | 163.02 | 9.533 | 8.998 |
| Giza 11 | 50 | 19.93 | 18.02 | 56.24 | 50.00 | 29.09 | 26.33 | 7.58 | 7.15 | 220.72 | 188.39 | 9.837 | 9.330 |
| | 70 | 21.26 | 18.87 | 60.78 | 53.21 | 31.86 | 29.34 | 7.77 | 7.34 | 247.71 | 215.48 | 9.967 | 9.452 |
| | 30 | 20.59 | 17.83 | 50.37 | 44.43 | 22.29 | 20.96 | 7.11 | 6.67 | 158.68 | 140.09 | 9.129 | 8.629 |
| Giza 12 | 50 | 21.36 | 18.76 | 55.87 | 49.11 | 26.43 | 24.01 | 7.27 | 6.88 | 192.59 | 165.38 | 9.474 | 8.943 |
| | 70 | 22.79 | 19.88 | 59.44 | 52.54 | 28.53 | 26.70 | 7.48 | 7.05 | 214.07 | 188.68 | 9.603 | 9.115 |
| L.S.D. at 5 % | | 3.26 | 2.65 | 5.51 | 5.11 | 3.43 | 3.27 | N.S. | N.S. | 17.06 | 14.88 | N.S. | N.S. |
| | | Seed yield/plant (g) | | Seed yield/fed (kg) | | Harvest index (%) | | Seed oil content (%) | | Oil yield/plant (g) | | Oil yield/fed (kg) | |
| | 30 | 0.528 | 0.412 | 342.50 | 307.67 | 10.25 | 9.94 | 36.13 | 35.32 | 0.191 | 0.146 | 123.44 | 108.40 |
| Sakha 3 | 50 | 0.693 | 0.521 | 449.75 | 386.67 | 11.10 | 10.03 | 37.42 | 36.40 | 0.260 | 0.190 | 168.06 | 140.46 |
| | 70 | 0.798 | 0.608 | 497.83 | 452.33 | 10.89 | 10.79 | 38.58 | 37.74 | 0.308 | 0.230 | 191.87 | 170.43 |
| | 30 | 1.769 | 1.472 | 677.58 | 633.83 | 16.58 | 16.38 | 40.74 | 38.77 | 0.723 | 0.571 | 275.67 | 245.70 |
| Giza 11 | 50 | 2.178 | 1.761 | 748.17 | 714.58 | 15.69 | 15.54 | 41.79 | 40.46 | 0.913 | 0.715 | 312.30 | 288.71 |
| | 70 | 2.477 | 2.040 | 818.25 | 782.00 | 15.65 | 15.64 | 43.45 | 41.66 | 1.080 | 0.851 | 355.06 | 325.57 |
| | 30 | 1.454 | 1.213 | 636.50 | 570.17 | 15.46 | 14.59 | 41.17 | 39.09 | 0.601 | 0.474 | 261.72 | 222.84 |
| Giza 12 | 50 | 1.830 | 1.482 | 720.55 | 652.33 | 14.80 | 14.00 | 42.38 | 40.83 | 0.778 | 0.607 | 304.98 | 266.06 |
| | 70 | 2.060 | 1.722 | 779.43 | 713.00 | 14.39 | 14.06 | 43.86 | 41.91 | 0.908 | 0.723 | 341.38 | 298.58 |
| L.S.D. at 5 % | | 0.126 | 0.120 | 45.99 | 42.16 | 0.64 | 0.62 | N.S. | N.S. | 0.187 | 0.165 | 38.07 | 30.00 |

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

Mean values of upper branching zone length, No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed yield/plant, seed yield/fed, harvest index, oil yield/plant and oil yield/fed were significantly affected by interaction between flax cultivars and plant densities treatments in both seasons, as shown in **Table 8.** While, mean values in No. of seeds/capsule, seed index and seed oil content were not significantly affected by interaction between flax cultivars and plant densities treatments in both seasons. Giza 11 cultivar at 1500 seeds/$m^2$ recorded the greatest mean values in No. of upper branches/plant (64.20 and 55.96 upper branches), No. of capsules/plant (32.65 and 30.13 capsules), No. of

seeds/plant (248.71 and 217.77 seeds), seed yield/plant (2.508 and 2.070 g), harvest index (16.71 and 16.63 %) and oil yield/plant (1.090 and 0.849 g) during two seasons, respectively. However, planting the same flax cultivar with the highest plant density (2500 seeds/$m^2$) significantly gave the maximum mean values of seed yield/fed (791.50 and 755.50 kg) and oil yield/fed (323.97 and 299.22 kg) in the first and second seasons, respectively. While, Sakha 3 cultivar with 2500 seeds/$m^2$ produced the lowest mean values in No. of upper branches/plant (31.29 and 27.21 upper branches), No. of capsules/plant (12.68 and 10.68 capsules), No. of seeds/plant (102.71 and 81.67 seeds), seed yield/plant (0.564 and 0.439 g), harvest index (10.19 and 9.77 %) and oil yield/plant (0.206 and 0.156 g) during two seasons, respectively. However, flax planting at 1500 seeds/$m^2$ from the same cultivar significantly gave the minimum mean values of seed yield/fed (390.75 and 345.17 kg) and oil yield/fed (149.87 and 130.70 kg) in both seasons, respectively. The longest mean values of upper branching zone length which were 27.98 and 26.18 cm in both seasons, respectively which were obtained from Sakha 3 cultivar with plant density of 1500 seeds/$m^2$. Whereas, Giza 11 cultivar with plant density of 2500 seeds/$m^2$ gave the shortest mean values of upper branching zone length of 17.57 and 15.42 cm in the first and second seasons, respectively. The results agree with those reported by **Khan *et al*. 2005; Kocjan-Ačko and Trdan 2008; Lafond *et al.* 2008; Ahmed 2010; Irvine *et al*. 2010; Laza and Pop 2012; Andruszczak *et al.* 2015; El-Borhamy 2016; Erdoğdu *et al*. 2018 and Sarkees and Mahmood 2018**, whose concluded that mean values of seed and oil yield and its related traits were significantly affected by interaction of flax cultivars and plant densities.

**Table 8**. Mean values of seed and oil 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/$m^2$) | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Sakha 3 | 1500 | 27.98 | 26.18 | 41.78 | 37.16 | 16.15 | 13.64 | 8.31 | 7.94 | 134.52 | 108.54 | 5.792 | 5.520 |
| | 2000 | 25.90 | 24.47 | 36.76 | 32.96 | 14.32 | 11.78 | 8.25 | 7.76 | 118.40 | 91.55 | 5.650 | 5.449 |
| | 2500 | 24.39 | 22.26 | 31.29 | 27.21 | 12.68 | 10.68 | 8.08 | 7.64 | 102.71 | 81.67 | 5.470 | 5.350 |
| Giza 11 | 1500 | 22.20 | 19.95 | 64.20 | 55.96 | 32.65 | 30.13 | 7.60 | 7.21 | 248.71 | 217.77 | 10.069 | 9.491 |
| | 2000 | 20.35 | 18.21 | 56.57 | 49.81 | 29.38 | 25.96 | 7.60 | 7.15 | 223.99 | 185.94 | 9.793 | 9.233 |
| | 2500 | 17.57 | 15.42 | 47.88 | 42.70 | 24.33 | 23.03 | 7.41 | 7.07 | 180.64 | 163.18 | 9.476 | 9.056 |
| Giza 12 | 1500 | 24.45 | 21.64 | 62.53 | 55.28 | 29.29 | 27.36 | 7.44 | 7.01 | 218.41 | 192.36 | 9.657 | 9.114 |
| | 2000 | 22.11 | 18.98 | 55.78 | 48.78 | 26.68 | 23.60 | 7.28 | 6.85 | 194.76 | 161.93 | 9.390 | 8.856 |
| | 2500 | 18.18 | 15.85 | 47.36 | 42.01 | 21.28 | 20.71 | 7.14 | 6.74 | 152.18 | 139.86 | 9.159 | 8.718 |
| **L.S.D. at 5 %** | | **2.75** | **2.53** | **5.23** | **4.99** | **3.17** | **3.01** | **N.S.** | **N.S.** | **14.48** | **13.06** | **N.S.** | **N.S.** |
| | | Seed yield/plant (g) | | Seed yield/fed (kg) | | Harvest index (%) | | Seed oil content (%) | | Oil yield/plant (g) | | Oil yield/fed (kg) | |
| Sakha 3 | 1500 | 0.781 | 0.601 | 390.75 | 345.17 | 11.42 | 10.81 | 38.23 | 37.70 | 0.300 | 0.227 | 149.87 | 130.70 |
| | 2000 | 0.672 | 0.501 | 432.67 | 385.17 | 10.64 | 10.18 | 37.52 | 36.41 | 0.253 | 0.183 | 162.88 | 140.85 |
| | 2500 | 0.564 | 0.439 | 466.67 | 416.33 | 10.19 | 9.77 | 36.38 | 35.36 | 0.206 | 0.156 | 170.62 | 147.74 |
| Giza 11 | 1500 | 2.508 | 2.070 | 698.08 | 656.67 | 16.71 | 16.63 | 43.28 | 40.83 | 1.090 | 0.849 | 302.80 | 268.89 |
| | 2000 | 2.200 | 1.721 | 754.42 | 718.25 | 15.78 | 15.64 | 41.85 | 40.53 | 0.924 | 0.700 | 316.26 | 291.87 |
| | 2500 | 1.715 | 1.482 | 791.50 | 755.50 | 15.43 | 15.29 | 40.84 | 39.53 | 0.703 | 0.588 | 323.97 | 299.22 |
| Giza 12 | 1500 | 2.112 | 1.756 | 661.07 | 586.25 | 15.52 | 14.70 | 43.82 | 41.20 | 0.930 | 0.727 | 290.50 | 242.38 |
| | 2000 | 1.834 | 1.439 | 720.25 | 658.08 | 14.66 | 14.09 | 42.24 | 40.49 | 0.777 | 0.585 | 304.76 | 267.07 |
| | 2500 | 1.398 | 1.223 | 755.17 | 691.17 | 14.48 | 13.86 | 41.34 | 40.14 | 0.580 | 0.493 | 312.82 | 278.03 |
| **L.S.D. at 5 %** | | **0.118** | **0.107** | **40.77** | **37.72** | **0.43** | **0.36** | **N.S.** | **N.S.** | **0.170** | **0.163** | **34.88** | **34.21** |

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

Mean values in No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed yield/plant and seed yield/fed were significantly affected by interaction between nitrogen fertilizer rates and plant densities treatments during both seasons, While, mean values of upper branching zone length, No. of seeds/capsule, seed index, harvest index, seed oil content, oil yield/plant and oil yield/fed were not significantly affected by interaction between flax cultivars and plant densities treatments in both seasons, as shown in **Table 9.** The greatest mean values in No. of upper branches/plant (60.26 and 52.92 upper branches), No. of capsules/plant (28.91 and 26.31 capsules), No. of seeds/plant (228.65 and

196.72 seeds) and seed yield/plant (2.079 and 1.701 g) were obtained from flax planting when received 70 kg N/fed at plant density of 1500 seeds/m$^2$, also sowing flax under the same nitrogen fertilizer rates with 2500 seeds/m$^2$ recorded the maximum mean values of seed yield/fed (739.75 and 692.00 kg) in the first and second seasons, respectively. On the other hand, the lowest mean values in No. of upper branches/plant (37.66 and 33.75 upper branches), No. of capsules/plant (16.94 and 15.88 capsules), No. of seeds/plant (123.15 and 109.16 seeds) and seed yield/plant (1.006 and 0.857 g) were obtained from flax planting under soil fertilized by 30 kg N/fed at plant density of 2500 seeds/m$^2$, also sowing flax under the same nitrogen fertilizer rates with 1500 seeds/m$^2$ recorded the lowest mean values of seed yield/fed (510.75 and 456.50 kg) in the both seasons, respectively. These results are in agreement with that were obtained by **Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Shaker *et al.* 2012; Andruszczak *et al.* 2015 and El-Borhamy 2016.**

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

| Nitrogen rate (kg N/fed) | Plant density (seeds/m$^2$) | Upper branching zone length (cm) | | No. of upper branches /plant | | No. of capsules/plant | | No. of seeds/capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1$^{st}$ | 2$^{nd}$ | 1$^{st}$ | 2$^{nd}$ | 1$^{st}$ | 2$^{nd}$ | 1$^{st}$ | 2$^{nd}$ | 1$^{st}$ | 2$^{nd}$ | 1$^{st}$ | 2$^{nd}$ |
| | 1500 | 23.93 | 21.62 | 52.54 | 45.34 | 22.66 | 20.83 | 7.56 | 7.19 | 168.83 | 147.24 | 8.327 | 7.877 |
| 30 | 2000 | 21.77 | 19.34 | 45.02 | 40.13 | 20.20 | 17.98 | 7.47 | 7.05 | 148.56 | 124.95 | 7.986 | 7.575 |
| | 2500 | 18.68 | 16.84 | 37.66 | 33.75 | 16.94 | 15.88 | 7.36 | 6.98 | 123.15 | 109.16 | 7.773 | 7.428 |
| | 1500 | 24.80 | 22.51 | 55.71 | 50.15 | 26.53 | 23.99 | 7.80 | 7.40 | 204.15 | 174.70 | 8.547 | 8.074 |
| 50 | 2000 | 22.55 | 20.45 | 50.06 | 44.02 | 23.78 | 20.43 | 7.76 | 7.26 | 182.21 | 146.29 | 8.339 | 7.906 |
| | 2500 | 20.06 | 17.96 | 42.34 | 37.54 | 19.99 | 18.08 | 7.54 | 7.18 | 148.98 | 128.07 | 8.088 | 7.748 |
| | 1500 | 25.89 | 23.65 | 60.26 | 52.92 | 28.91 | 26.31 | 7.99 | 7.58 | 228.65 | 196.72 | 8.643 | 8.175 |
| 70 | 2000 | 24.05 | 21.87 | 54.04 | 47.39 | 26.40 | 22.92 | 7.91 | 7.44 | 206.37 | 168.19 | 8.508 | 8.056 |
| | 2500 | 21.40 | 18.73 | 46.53 | 40.63 | 21.36 | 20.47 | 7.73 | 7.28 | 163.39 | 147.49 | 8.244 | 7.947 |
| L.S.D. at 5 % | | N.S. | N.S. | 5.23 | 4.99 | 3.17 | 3.01 | N.S. | N.S. | 14.48 | 13.06 | N.S. | N.S. |

| | | Seed yield/plant (g) | | Seed yield/fed (kg) | | Harvest index (%) | | Seed oil content (%) | | Oil yield/plant (g) | | Oil yield/fed (kg) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1500 | 1.487 | 1.234 | 510.75 | 456.50 | 14.66 | 13.92 | 40.49 | 38.18 | 0.616 | 0.477 | 210.05 | 175.73 |
| 30 | 2000 | 1.258 | 1.005 | 554.08 | 512.42 | 13.91 | 13.64 | 39.49 | 37.72 | 0.507 | 0.387 | 221.90 | 195.89 |
| | 2500 | 1.006 | 0.857 | 591.75 | 542.75 | 13.72 | 13.35 | 38.06 | 37.28 | 0.392 | 0.327 | 228.87 | 205.32 |
| | 1500 | 1.836 | 1.491 | 588.05 | 535.08 | 14.48 | 13.97 | 41.57 | 40.27 | 0.780 | 0.612 | 247.48 | 217.96 |
| 50 | 2000 | 1.604 | 1.220 | 648.58 | 590.25 | 13.70 | 12.98 | 40.42 | 39.26 | 0.663 | 0.489 | 265.19 | 234.63 |
| | 2500 | 1.260 | 1.053 | 681.83 | 628.25 | 13.41 | 12.61 | 39.60 | 38.16 | 0.508 | 0.411 | 272.66 | 242.64 |
| | 1500 | 2.079 | 1.701 | 651.10 | 596.50 | 14.50 | 14.25 | 43.28 | 41.28 | 0.923 | 0.714 | 285.63 | 248.28 |
| 70 | 2000 | 1.845 | 1.435 | 704.67 | 658.83 | 13.46 | 13.28 | 41.70 | 40.45 | 0.784 | 0.592 | 296.81 | 269.28 |
| | 2500 | 1.411 | 1.234 | 739.75 | 692.00 | 12.96 | 12.96 | 40.91 | 39.59 | 0.589 | 0.499 | 305.88 | 277.03 |
| L.S.D. at 5 % | | 0.118 | 0.107 | 40.77 | 37.72 | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

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

The effect of interaction between flax cultivars, nitrogen fertilizer rates and plant densities treatments under study on mean values in No. of upper branches/plant, No. of capsules/plant, No. of seeds/plant, seed yield/plant, seed yield/fed and harvest index which significant in two seasons. While, mean values of upper branching zone length, No. of seeds/capsule, seed index, seed oil content, oil yield/plant and oil yield/fed were not significantly affected by interaction **(Tables 10 and 11).** The greatest mean values in No. of upper branches/plant (68.98 and 59.76 upper branches), No. of capsules/plant (35.88 and 33.22 capsules), No. of seeds/plant (280.94 and 246.16 seeds) and seed yield/plant (2.880 and 2.382 g) in two seasons, respectively, were obtained from Giza 11 cultivar under soil fertilized by 70 kg N/fed at plant density of 1500 seeds/m$^2$. On the other hand, Sakha 3 cultivar when received 30 kg N/fed at plant density of 2500 seeds/m$^2$ gave the lowest mean values in No. of upper branches/plant (27.58 and 24.65 upper branches), No. of capsules/plant (10.95 and 9.25 capsules), No. of seeds/plant (86.40 and 69.47 seeds), seed yield/plant (0.452 and 0.358 g) in both seasons, respectively. The maximum mean values of seed yield/fed (865.25 and 830.50 kg in the respective two seasons) were obtained from Giza 11 cultivar when received 70 kg N/fed at plant density of 2500 seeds/m$^2$. Whereas, the lowest mean values of seed yield/fed were obtained

from Sakha 3 cultivar under soil fertilized by 30 kg N/fed at plant density of 1500 seeds/$m^2$ which were 310.25 and 270.00 kg in the respective two seasons. The highest mean values of harvest index (17.23 and 16.97 % in the respective two seasons) were obtained from flax planting cultivar of Giza 11 with received 30 kg N/fed at plant density of 1500 seeds/$m^2$. Whereas, the lowest mean values of harvest index were obtained from Sakha 3 cultivar with plant density of 2500 seeds/$m^2$ under soil fertilized by 30 and 50 kg N/fed which were 9.77 and 9.58 % in the first and second seasons, respectively. The results agree with those reported by **Lafond *et al.* 2008; Ahmed 2010; Laza and Pop 2012; Andruszczak *et al.* 2015 and El-Borhamy 2016.**

**Table 10.** Mean values of flax upper branching zone length, No. of upper branches/plant, No. of capsules/plant, No. of seeds/capsule, No. of seeds/plant and seed index as affected by interaction between flax cultivar, nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

| Treatment | | | Upper branching zone length (cm) | | No. of upper branches/plant | | No. of capsules /plant | | No. of seeds /capsule | | No. of seeds/plant | | Seed index (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| | | 1500 | 26.75 | 25.00 | 38.56 | 33.68 | 13.57 | 11.56 | 8.12 | 7.76 | 110.19 | 89.71 | 5.629 | 5.353 |
| | 30 | 2000 | 24.71 | 23.40 | 33.53 | 30.25 | 11.76 | 10.02 | 8.02 | 7.54 | 94.32 | 75.55 | 5.418 | 5.253 |
| | | 2500 | 23.16 | 21.47 | 27.58 | 24.65 | 10.95 | 9.25 | 7.89 | 7.51 | 86.40 | 69.47 | 5.227 | 5.152 |
| | | 1500 | 28.06 | 26.04 | 41.23 | 37.57 | 16.54 | 13.97 | 8.35 | 7.98 | 138.11 | 111.48 | 5.826 | 5.562 |
| Sakha 3 | 50 | 2000 | 25.79 | 24.15 | 36.05 | 32.97 | 14.55 | 12.26 | 8.30 | 7.81 | 120.77 | 95.75 | 5.664 | 5.462 |
| | | 2500 | 24.49 | 22.21 | 30.73 | 27.29 | 13.22 | 10.25 | 8.11 | 7.67 | 107.21 | 78.62 | 5.498 | 5.343 |
| | | 1500 | 29.13 | 27.50 | 45.56 | 40.22 | 18.33 | 15.38 | 8.47 | 8.09 | 155.26 | 124.42 | 5.921 | 5.646 |
| | 70 | 2000 | 27.21 | 25.85 | 40.69 | 35.65 | 16.64 | 13.05 | 8.42 | 7.92 | 140.11 | 103.36 | 5.869 | 5.632 |
| | | 2500 | 25.53 | 23.10 | 35.55 | 29.68 | 13.88 | 12.54 | 8.25 | 7.73 | 114.51 | 96.93 | 5.685 | 5.554 |
| | | 1500 | 21.65 | 18.83 | 60.38 | 51.23 | 29.15 | 26.95 | 7.35 | 7.02 | 214.25 | 189.19 | 9.864 | 9.315 |
| | 30 | 2000 | 19.24 | 16.69 | 51.26 | 45.92 | 25.76 | 23.18 | 7.29 | 6.95 | 187.79 | 161.10 | 9.468 | 8.942 |
| | | 2500 | 15.89 | 14.54 | 43.26 | 38.65 | 21.32 | 20.23 | 7.16 | 6.86 | 152.65 | 138.78 | 9.268 | 8.737 |
| | | 1500 | 22.14 | 20.04 | 63.25 | 56.89 | 32.93 | 30.23 | 7.62 | 7.21 | 250.93 | 217.96 | 10.089 | 9.525 |
| Giza 11 | 50 | 2000 | 20.21 | 18.57 | 57.23 | 49.87 | 29.61 | 25.65 | 7.70 | 7.14 | 228.00 | 183.14 | 9.887 | 9.332 |
| | | 2500 | 17.45 | 15.46 | 48.23 | 43.23 | 24.73 | 23.11 | 7.41 | 7.10 | 183.25 | 164.08 | 9.535 | 9.132 |
| | | 1500 | 22.81 | 20.99 | 68.98 | 59.76 | 35.88 | 33.22 | 7.83 | 7.41 | 280.94 | 246.16 | 10.253 | 9.634 |
| | 70 | 2000 | 21.61 | 19.36 | 61.23 | 53.64 | 32.76 | 29.06 | 7.82 | 7.35 | 256.18 | 213.59 | 10.023 | 9.425 |
| | | 2500 | 19.36 | 16.27 | 52.14 | 46.23 | 26.93 | 25.75 | 7.65 | 7.25 | 206.01 | 186.69 | 9.626 | 9.298 |
| | | 1500 | 23.40 | 21.04 | 58.69 | 51.10 | 25.25 | 23.98 | 7.21 | 6.79 | 182.05 | 162.82 | 9.489 | 8.962 |
| | 30 | 2000 | 21.36 | 17.92 | 50.26 | 44.23 | 23.07 | 20.75 | 7.09 | 6.66 | 163.57 | 138.20 | 9.073 | 8.531 |
| | | 2500 | 17.00 | 14.52 | 42.15 | 37.95 | 18.55 | 18.15 | 7.03 | 6.57 | 130.41 | 119.25 | 8.825 | 8.395 |
| | | 1500 | 24.21 | 21.44 | 62.66 | 55.98 | 30.11 | 27.77 | 7.42 | 7.01 | 223.42 | 194.67 | 9.726 | 9.135 |
| Giza 12 | 50 | 2000 | 21.65 | 18.63 | 56.89 | 49.23 | 27.18 | 23.39 | 7.28 | 6.84 | 197.87 | 159.99 | 9.465 | 8.924 |
| | | 2500 | 18.23 | 16.22 | 48.05 | 42.11 | 22.01 | 20.87 | 7.11 | 6.78 | 156.49 | 141.50 | 9.231 | 8.769 |
| | | 1500 | 25.74 | 22.45 | 66.23 | 58.77 | 32.52 | 30.33 | 7.68 | 7.24 | 249.75 | 219.59 | 9.755 | 9.245 |
| | 70 | 2000 | 23.32 | 20.39 | 60.19 | 52.88 | 29.79 | 26.65 | 7.48 | 7.04 | 222.83 | 187.62 | 9.632 | 9.112 |
| | | 2500 | 19.30 | 16.81 | 51.89 | 45.97 | 23.27 | 23.12 | 7.29 | 6.87 | 169.64 | 158.83 | 9.421 | 8.989 |
| **L.S.D. at 5 %** | | | **N.S.** | **N.S.** | **9.06** | **8.64** | **5.49** | **5.22** | **N.S.** | **N.S.** | **25.08** | **22.62** | **N.S.** | **N.S.** |

**Table 11.** Mean values flax seed yield/plant, seed yield/fed, harvest index, oil content, oil yield/plant and oil yield/fed as affected by interaction between flax cultivar, nitrogen fertilizer rates and plant densities during 2018/2019 (1st) and 2019/2020 (2nd) seasons.

| Treatment | | | Seed yield /plant (g) | | Seed yield/fed (kg) | | Harvest index (%) | | Seed oil content (%) | | Oil yield/plant (g) | | Oil yield/fed (kg) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| | | 1500 | 0.620 | 0.480 | 310.25 | 270.00 | 10.83 | 10.05 | 37.21 | 36.56 | 0.231 | 0.176 | 115.44 | 98.71 |
| | 30 | 2000 | 0.511 | 0.397 | 340.50 | 310.75 | 10.15 | 10.07 | 36.56 | 35.15 | 0.187 | 0.139 | 124.49 | 109.23 |
| | | 2500 | 0.452 | 0.358 | 376.75 | 342.25 | 9.77 | 9.71 | 34.61 | 34.26 | 0.156 | 0.123 | 130.39 | 117.25 |
| | | 1500 | 0.805 | 0.620 | 402.50 | 350.50 | 11.49 | 10.88 | 38.26 | 37.55 | 0.308 | 0.233 | 154.00 | 131.61 |
| Sakha 3 | 50 | 2000 | 0.684 | 0.523 | 456.00 | 386.50 | 11.02 | 9.65 | 37.23 | 36.39 | 0.255 | 0.190 | 169.77 | 140.65 |
| | | 2500 | 0.589 | 0.420 | 490.75 | 423.00 | 10.79 | 9.58 | 36.76 | 35.25 | 0.217 | 0.148 | 180.40 | 149.11 |
| | | 1500 | 0.919 | 0.702 | 459.50 | 415.00 | 11.92 | 11.51 | 39.21 | 38.98 | 0.360 | 0.274 | 180.17 | 161.77 |
| | 70 | 2000 | 0.822 | 0.582 | 501.50 | 458.25 | 10.73 | 10.82 | 38.76 | 37.68 | 0.319 | 0.219 | 194.38 | 172.67 |
| | | 2500 | 0.651 | 0.538 | 532.50 | 483.75 | 10.01 | 10.03 | 37.76 | 36.56 | 0.246 | 0.197 | 201.07 | 176.86 |
| | | 1500 | 2.113 | 1.762 | 633.50 | 587.25 | 17.23 | 16.97 | 42.00 | 38.75 | 0.888 | 0.683 | 266.07 | 227.56 |
| | 30 | 2000 | 1.778 | 1.441 | 679.50 | 640.50 | 16.32 | 16.22 | 40.70 | 38.96 | 0.724 | 0.561 | 276.56 | 249.54 |
| | | 2500 | 1.415 | 1.213 | 719.75 | 673.75 | 16.17 | 15.96 | 39.51 | 38.59 | 0.559 | 0.468 | 284.37 | 260.00 |
| | | 1500 | 2.532 | 2.076 | 697.75 | 662.00 | 16.48 | 16.38 | 42.87 | 41.50 | 1.085 | 0.862 | 299.13 | 274.73 |
| Giza 11 | 50 | 2000 | 2.254 | 1.709 | 757.25 | 719.50 | 15.50 | 15.44 | 41.83 | 40.69 | 0.943 | 0.695 | 316.76 | 292.76 |
| | | 2500 | 1.747 | 1.498 | 789.50 | 762.25 | 15.10 | 14.79 | 40.66 | 39.18 | 0.710 | 0.587 | 321.01 | 298.65 |
| | | 1500 | 2.880 | 2.372 | 763.00 | 720.75 | 16.41 | 16.55 | 44.98 | 42.23 | 1.296 | 1.001 | 343.20 | 304.37 |
| | 70 | 2000 | 2.568 | 2.013 | 826.50 | 794.75 | 15.52 | 15.24 | 43.01 | 41.94 | 1.104 | 0.844 | 355.48 | 333.32 |
| | | 2500 | 1.983 | 1.736 | 865.25 | 830.50 | 15.01 | 15.13 | 42.36 | 40.82 | 0.840 | 0.709 | 366.52 | 339.01 |
| | | 1500 | 1.727 | 1.459 | 588.50 | 512.25 | 15.91 | 14.75 | 42.25 | 39.22 | 0.730 | 0.572 | 248.64 | 200.90 |
| | 30 | 2000 | 1.484 | 1.179 | 642.25 | 586.00 | 15.26 | 14.62 | 41.21 | 39.06 | 0.612 | 0.460 | 264.67 | 228.89 |
| | | 2500 | 1.151 | 1.001 | 678.75 | 612.25 | 15.22 | 14.38 | 40.05 | 38.99 | 0.461 | 0.390 | 271.84 | 238.72 |
| | | 1500 | 2.173 | 1.778 | 663.90 | 592.75 | 15.46 | 14.65 | 43.58 | 41.76 | 0.947 | 0.743 | 289.33 | 247.53 |
| Giza 12 | 50 | 2000 | 1.873 | 1.428 | 732.50 | 664.75 | 14.59 | 13.87 | 42.19 | 40.69 | 0.790 | 0.581 | 309.04 | 270.49 |
| | | 2500 | 1.445 | 1.241 | 765.25 | 699.50 | 14.36 | 13.47 | 41.37 | 40.05 | 0.598 | 0.497 | 316.58 | 280.15 |
| | | 1500 | 2.436 | 2.030 | 730.80 | 653.75 | 15.18 | 14.69 | 45.64 | 42.63 | 1.112 | 0.865 | 333.54 | 278.69 |
| | 70 | 2000 | 2.146 | 1.710 | 786.00 | 723.50 | 14.14 | 13.78 | 43.33 | 41.72 | 0.930 | 0.713 | 340.57 | 301.84 |
| | | 2500 | 1.598 | 1.428 | 821.50 | 761.75 | 13.86 | 13.71 | 42.61 | 41.38 | 0.681 | 0.591 | 350.04 | 315.21 |
| **L.S.D. at 5 %** | | | **0.204** | **0.186** | **70.62** | **65.34** | **0.75** | **0.63** | **N.S.** | **N.S.** | **N.S.** | **N.S.** | **N.S.** | **N.S.** |

## Conclusion:

From the obtained results of this study it could be concluded that flax planting cultivar of Giza 11 and fertilizing by 70 kg N/fed with plant density of 2500 seeds/$m^2$ to maximizing seed and oil yield/fed.

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# محصول البذور و صفات الجودة لبعض أصناف الكتان و تأثرها بمعدلات السماد النيتروجيني و الكثافة النباتية

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أجريت تجربتان حقليتان في مزرعة محطة البحوث الزراعية بالجميزة - محافظة الغربية - مركز البحوث الزراعية - مصر خلال الموسمين الشتويين 2019/2018 و 2020/2019، لدراسة مدى تأثر محصول البذور والزيت و الصفات المرتبطة به لثلاثة أصناف من الكتان هي سخا 3 (صنف كتان ألياف)، جيزة 11 و جيزة 12(صنف كتان ثنائي الغرض) بثلاثة معدلات من السماد النيتروجيني (30، 50 و 70 كجم ن/فدان) و ثلاثة كثافات نباتية (1500، 2000 و 2500 بذرة/م$^2$). 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 البذور والزيت و الصفات المرتبطة به خلال موسمي الدراسة. زراعة صنف الكتان جيزة 11 حقق معنوياً أفضل متوسط قيم لصفات عدد الأفرع القمية/نبات، عدد الكبسولات/نبات، عدد البذور/نبات، دليل البذرة، محصول البذور/فدان، دليل الحصاد، محصول الزيت/نبات و محصول الزيت/فدان خلال موسمي التجربة. بينما أفضل متوسط قيم لصفات المحصول البيولوجي/فدان و نسبة الزيت في البذور تم الحصول عليهم من زراعة صنف الكتان جيزة 12 خلال موسمي الدراسة. بينما زراعة الكتان صنف سخا 3 أنتج معنوياً أعلى متوسط قيم لصفات طول منطقة التفريع القمية و عدد البذور/كبسولة خلال موسمي الدراسة.

زيادة معدلات السماد النيتروجيني من 30 إلى 70 كجم نيتروجين/فدان أدت إلى زيادة معنوية في معظم الصفات المدروسة لمحصول البذور والزيت و الصفات المرتبطة به في كلا الموسمين.

زراعة نباتات الكتان عند كثافة نباتية 1500 بذرة/م$^2$ أعطت معنوياً أفضل متوسط قيم لصفات طول منطقة التفريع القمية، عدد الأفرع القمية/نبات، عدد الكبسولات/نبات، عدد البذور/نبات، محصول البذور/نبات، دليل الحصاد و محصول الزيت/نبات خلال موسمي الدراسة. بينما زراعة نباتات الكتان عند كثافة نباتية 2500 بذرة/م$^2$ حققت معنوياً أفضل متوسط قيم لصفات محصول البذور/فدان، المحصول البيولوجي/فدان و محصول الزيت/فدان خلال موسمي الدراسة.

التفاعلات من الدرجة الأولى بين معاملات جيزة 11 X 70 كجم نيتروجين/فدان، جيزة 11 X 1500 بذرة/م$^2$ و 70 كجم نيتروجين/فدان X 1500 بذرة/م$^2$ و التفاعل من الدرجة الثانية بين معاملات جيزة 11 X 70 كجم نيتروجين/فدان X 1500 بذرة/م$^2$ حققت معنويا أعلى متوسط قيم لصفات محصول البذور و الزيت للنباتات الفردية مقارنة بالتفاعلات بين المعاملات الأخري في كلا الموسمين. بينما أعلى متوسط قيم لصفات محصول البذور و الزيت للفدان تم الحصول عليها من التفاعلات من الدرجة الأولى بين المعاملات جيزة 11 X 70 كجم نيتروجين/فدان، جيزة 11 X 2500 بذرة/م$^2$ و 70 كجم نيتروجين/فدان X 2500 بذرة/م$^2$ و التفاعل من الدرجة الثانية بين المعاملات جيزة 11 X 70 كجم نيتروجين/فدان X2500 بذرة/م$^2$.

**الخلاصة:**

توصي النتائج بزراعة الكتان صنف جيزة 11 مع التسميد النيتروجيني بمعدل 70 كجم نيتروجين/فدان عند كثافة نباتية 2500 بذرة/م$^2$ حيث عظمت إنتاجية محصول البذور و الزيت بوحدة المساحة.