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Evaluation of some Flax (*Linum usitatissimum* L.) Genotypes under different Nitrogen Fertilizer Sources

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ABSTRACT

Two field trials were conducted at the Experimental Farm of Sakha Agricultural Research Station in Egypt for the 2021/2022 and 2022/2023 seasons, to evaluate the performance of some flax genotypes (Strain 651 (S.651), Sakha 3, 5 and Giza12) under different nitrogen fertilizer sources; ammonium sulfate (20.6% N), ammonium nitrate (33.5% N) and urea (46.5% N). For the experiment design, split-plot design was used with four replicates. Three different nitrogen fertilizer sources were allocated to the main plots, while four flax genotypes were allocated to the sub-plots. The results indicated that the use of ammonium sulfate treatment achieved significantly highest values for most of the studied traits, followed by ammonium nitrate treatment, whilst using urea recorded the lowest ones during both seasons. The results also, referred that S.651 was significantly superior to the rest of other genotypes in technical length, fiber length, fiber percentage and fiber yield/fed within both seasons. Giza12 recorded significantly the most beneficial results for stem diameter, straw yield/plant, straw yield/fed, fruiting zone length, seed index and seed yield/plant over both seasons. Moreover, Sakha 5 significantly outperformed other genotypes in number of capsules/plant, seed yield/fed, oil percentage and oil yield/fed during the 1st and 2nd seasons. Consequently, this study recommended the usage of the nitrogen source of ammonium sulfate or ammonium nitrate with the promising flax strain S.651 to obtain the highest fiber yield/fed, or with Sakha5 the oil type cultivar to gain the highest seed and oil yield/fed in Northern Delta region of Egypt.

Keywords: Flax; nitrogen sources; oil yield; fiber yield.

INTRODUCTION

One of the annuals in the Linaceae family is flax (*Linum usitatissimum* L.). Flax is an old fiber crop and for thousands of years the ancient Egyptians were familiar with flax and had grown the plant for its fiber, which was used to make linen yarn and cloth, furthermore for its edible seeds, known as flaxseed or linseed, which is used to extract linseed oil. Even though the introduction of synthetic fibers has lowered the value of flax as a commercial fiber crop, flaxseed has increased in popularity as a healthy food. Because of their high levels of omega-3 fatty acids, the cultivation and consumption of flaxseed is increasing as a source of healthy oil, consequently flax is still commercially significant in several nations throughout the world, including China, Russia, and Canada. Many products and industries are based on the flax plant, such as towels, clothes, and other textiles made from the long fibers spun into linen yarns. While paper twin and packaging are all made from the short fibers (tow). Furthermore, flax seeds are ground and utilized to produce linseed meal and oil. Oil is used to make paints, varnishes, printing ink, oil cloth, and soap because it dries quickly in the air (Abdelmasieh *et al.*, 2023). Egypt's total area under cultivation for flax crop was approximately 8609 hectares in the 2021 season, yielding 7600.74 tons of fiber (FAO, 2023).

Nitrogen is frequently the most essential plant nutrient since it controls the amount of protein, protoplasm, and chlorophyll produced, resulting in increased cell size, leaf area and photosynthesis activity. As a result, flax showed a very good reaction to nitrogen (Abd Eldaiem and El-Borhamy, 2015). Some problems appeared by frequent application of mineral fertilizers, for example sixty percent or more of applied nitrogen is lost primarily through evaporation or leaching during drainage. The problem is not only the loss of nitrogen, which generates reasonable economic losses, but it also concerns underground water poisoning and other hazardous environmental pollution hazards (Yasin *et al.*, 2012). Hafez and Kobata (2012) reported that the response of the spikelet number in wheat, a crucial component of wheat production, to applied nitrogen from ammonium sulfate was greater than that from urea in all tested cultivars. El Mantawy (2017) found that during the two seasons, the growth, yield, yield components, and yield quality of sunflower plants were significantly impacted by various nitrogen sources. Notable outcomes were observed at nitrogen sources such as ammonium sulfate, ammonium nitrate, and urea. Emam (2019) examined the impact of nitrogen fertilization sources as a soil application on flax and stated that ammonium nitrate followed by ammonium sulfate as nitrogen source gave the highest straw and seed yields and their associated properties compared to urea.

Egypt has a limited amount of land available for agriculture, thus the only option to make up for this is to plant new, highly productive varieties. The potential yield of different flax genotypes varied depending on several physiological processes impacted by both genetics and environment. New, enhanced, high-yielding and disease-resistant varieties must take the place of the outdated ones in farmer fields (Singh, 2013). Elayan *et al.* (2018) observed that

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when zinc was applied at 300 ppm and nitrogen at 60 kg/fed, flax strain 651 ranked top in terms of fiber % per total cross section, followed by S. 541-D/10 and S. 541-C/3. Mahmoud *et al.* (2022) indicated that the new promising strain (S.651) had the highest percentage of total fiber. According to Elsorady *et al.* (2022), the new flax strain (S.651) had the highest technical length value, whilst the flax genotypes Giza 12 and Giza 11 provided the maximum straw yield per plant and straw yield per hectare. S.651 also contained the most fiber and moisture of any strain. Furthermore, the flaxseed Sakha 5 genotype had the most oil content, while the flaxseed Sakha 3 genotype had the least.

For these reasons, this evaluation was conducted to find a suitable nitrogen fertilizer source for increasing productivity and reducing expenses, as well as obtaining new, high-yielding cultivars to replace the old ones at Sakha, Kafr El-Sheikh Governorate in Egypt.

MATERIALS AND METHODS

Field trials were carried out during the two winter seasons of 2021/22 and 2022/23 at the Sakha Agricultural Research Station Experimental Farm, Agricultural Research Center (ARC), Egypt. In addition to obtaining new, high-yielding cultivars to replace the old ones for the highest flax yield and its features, the major goals of this investigation are to determine a suitable source of nitrogen fertilizer, increase productivity, and lower expenses.

The experimental design was a split-plot design with four replicates, with each experimental sub-plot area measuring 6 m^2 (2 x 3 m). The main-plots were attributed to the three nitrogen fertilizer sources; ammonium sulfate (20.6% N), ammonium nitrate (33.5% N) and urea (46.5% N) as a soil application, whereas the sub-plots were assigned to the four flax genotypes; Strain 651 (S.651) (fiber type), Sakha 3 (fiber type), Sakha 5 (oil type), and Giza 12 (dual type). Table 1 shows the pedigree of the selected flax genotypes.

Table 1. The pedigree of the selected flax genotypes

No.	Genotypes	Classification	Source
1-	Strain 651	Fiber type	(I.1563) x (S. 402/1 x Iriana)
2-	Sakha 3	Fiber type	I.Belinka x I.2569
3-	Sakha 5	Oil type	I.370 x I.2561
4-	Giza 12	Dual type	S.2419/1 x S.148

The soil texture at the experimental location is clay. Maize was the previous summer crop during both research seasons. Mechanical and chemical analyses for the experimental locations in the first and second seasons were carried out according to the manner specified by Page (1982) and are tabulated in Table 2.

Nitrogen fertilizer source treatments were administered as a soil application at a rate of 45 kg N/fed in two equal doses, with the first half of the nitrogen applied before the second irrigation and the second half before the third irrigation. During soil preparation, all phosphorus-requiring fertilizer, in the form of calcium super phosphate (15.5% P_2O_5), was applied at a rate of 100 kg/fed.

Over both seasons, recommended seed rate for each genotype was sown on November 2nd and November 1st, respectively, using the broadcast sowing method. The Ministry of Agriculture and Land Reclamation's guidelines were followed for the other flax agricultural techniques, which were maintained as usual.

Table 2. Physical and chemical properties of the experimental site during 2021/2022 and 2022/2023 seasons.

Properties		2021/2022 season	2022/2023 season
A: Mechanical analysis:			
Sand %		9.80	9.64
Silt %		29.90	30.25
Clay %		60.30	60.11
Texture		Clayey	Clayey
B: Chemical analysis:			
pH		7.72	7.82
EC ds/m		1.98	2.17
Organic matter %		1.25	1.30
Available mg/kg	N	27.10	26.50
	P	8.65	8.75
	K	260.50	270.70
Soluble cations meq/L	Ca^{++}	7.42	7.81
	Mg^{++}	1.76	1.89
	Na^{+}	8.91	9.11
	K^{+}	0.33	0.36
Soluble anions meq/L	$CO3^{--}$	0	0
	$HCO3^{-}$	4.28	4.01
	Cl^{-}	8.92	9.25
	$SO4^{--}$	5.22	5.91

The studied characters:

Ten guarded plants were randomly chosen from each sub-plot to record yield attributes at harvest time. Straw yield/fed (ton), seed yield/fed (kg), oil yield/fed (kg) and also fiber yield/fed (kg) were calculated from the whole sub-plot area basis. The seed oil percentage was determined using the method outlined by A.O.A.C. (1990), which used petroleum ether at (40–50°C) in a Soxhlet apparatus. Oil yield/fed (kg) was determined by multiplying seed oil percentage and seed yield/fed. Fiber percentage was determined by (weight of fiber yield/weight of straw yield after retting) x 100.

Yields and its components:

Straw yield and its features were: technical length (cm), stem diameter (mm), straw yield/plant (g) and straw yield/fed (ton).

Seed yield and its features were: fruiting zone length (cm), number of capsules/plant, seed index (weight of 1000 seeds) (g), seed yield/plant (g) and also seed yield/fed (kg).

Oil yield and its features were: oil percentage and oil yield/fed (kg).

Fiber yield and its features were: fiber length (cm), fiber percentage and fiber yield/fed (kg).

Statistical analysis:

Data were statistically analyzed using analysis of variance (ANOVA) for split-plot design as described by Gomez and Gomez (1984) using the software package “MSTAT-C”. Furthermore, treatment means were compared using the least significant difference (LSD) approach at the 5% level of probability, as outlined by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Straw yield and its features:

According to the results shown in Table 3, the three nitrogen fertilizer sources (ammonium sulfate, ammonium nitrate and urea) have a significant impact on straw yield and its features; technical length, stem diameter, straw yield/plant and also straw yield/fed, during the first and second seasons. The results obtained showed that the application of ammonium sulfate as a source of nitrogen fertilizer outperformed the rest of the other sources in the studied straw yield traits, but there were no significant differences in technical length, stem diameter and straw yield/fed between it and ammonium nitrate, while urea came in the last place, achieving the lowest values for the studied traits within both growing seasons. These findings are primarily related to the fact that the leaked nitrogen increased with the increase in the amount of applied nitrogen, and amount of leaked nitrogen from the urea was higher than that from the ammonium sulfate or ammonium nitrate. In addition, ammonium sulfate may have reduced the loss of nitrogen volatilization by sulfur ions. These findings are in accordance with those obtained by Buresh and De Datta (1990), Bijay and Yadvinder (2003), Hafez and Kobata (2012), Yasin *et al*. (2012), Abd Eldaiem and El-Borhamy (2015), El Mantawy (2017) and Emam (2019).

Flax genotype Giza 12 (dual purpose type) produced the best results for stem diameter, straw yield/plant and straw yield/fed throughout both growing seasons, and it was found to significantly outperformed the other tested genotypes; S.651 (fiber type), Sakha 3 (fiber type), and Sakha 5 (oil type) (Table 3). However, S.651 achieved the highest values concerning technical length only in both agronomic seasons. At the same time, the strain 651 achieved the lowest values for the other aforementioned studied traits. The primary cause of these findings is the variation in the four genotypes' genetic makeup and the potential of fiber, oil, and dual-purpose varieties of flax. The outcomes obtained by Elayan *et al.* (2018), Leilah *et al.* (2018), Kushwaha *et al.* (2019), Omar *et al.* (2020), Rashwan *et al.* (2020), Omar *et al.* (2021), Elsorady *et al.* (2022), Mahmoud *et al.* (2022) and Abdelmasieh *et al.* (2023) agree with these findings.

Table 3. Technical length, stem diameter, straw yield/plant and also per feddan of flax as influenced by nitrogen fertilizer sources and flax genotypes, furthermore their interaction during the 2021/2022 and 2022/2023 seasons.

Characters		Technical length (cm)		Stem diameter (mm)		Straw yield/plant (g)		Straw yield (ton/fed)	
Treatments		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Nitrogen fertilizer sources:									
Ammonium sulfate		79.6	82.1	1.8	2.1	1.62	1.70	3.501	3.654
Ammonium nitrate		76.8	79.0	1.7	1.9	1.40	1.58	3.264	3.434
Urea		73.4	77.1	1.6	1.7	1.29	1.47	2.921	3.174
LSD at 5 %		4.3	3.5	0.1	0.2	0.18	0.14	0.238	0.248
Flax genotypes:									
S.651		83.4	86.3	1.3	1.5	1.53	1.63	3.516	3.705
Sakha 3		80.0	82.6	1.5	1.7	1.40	1.51	3.337	3.504
Sakha 5		64.2	67.1	1.7	1.9	0.78	0.85	2.368	2.573
Giza 12		78.7	81.5	2.3	2.5	2.02	2.34	3.694	3.900
LSD at 5 %		7.4	6.7	0.3	0.3	0.18	0.06	0.169	0.180
Interaction:									
Ammonium sulfate	S.651	88.9	90.8	1.4	1.7	1.66	1.71	3.788	3.975
	Sakha 3	82.8	84.7	1.5	1.8	1.50	1.68	3.415	3.538
	Sakha 5	66.4	69.3	1.8	2.0	0.81	0.92	2.594	2.738
	Giza 12	80.0	83.6	2.6	2.7	2.50	2.48	4.206	4.363
Ammonium nitrate	S.651	84.3	86.1	1.3	1.5	1.53	1.67	3.543	3.669
	Sakha 3	79.4	82.1	1.5	1.6	1.45	1.54	3.414	3.531
	Sakha 5	65.0	66.6	1.7	1.8	0.78	0.84	2.448	2.684
	Giza 12	78.7	81.0	2.4	2.6	1.83	2.28	3.649	3.852
Urea	S.651	77.0	82.0	1.3	1.2	1.41	1.51	3.217	3.470
	Sakha 3	77.9	81.0	1.4	1.5	1.26	1.32	3.180	3.445
	Sakha 5	61.3	65.4	1.6	1.8	0.75	0.79	2.062	2.297
	Giza 12	77.4	80.0	2.1	2.3	1.73	2.27	3.227	3.485
LSD at 5 %		NS	NS	NS	NS	0.31	0.11	0.293	0.312

Straw yield/plant and straw yield/fed through each season was significantly impacted by the interaction impact between nitrogen fertilizer sources and flax genotypes (Table 3 and Figure 1). According to the presented findings, Giza 12 flax genotype and ammonium sulfate treatment were associated with the highest levels of the aforementioned traits, whereas the lowest values were obtained when treated with urea and Sakha 5 flax genotype during both seasons, respectively.

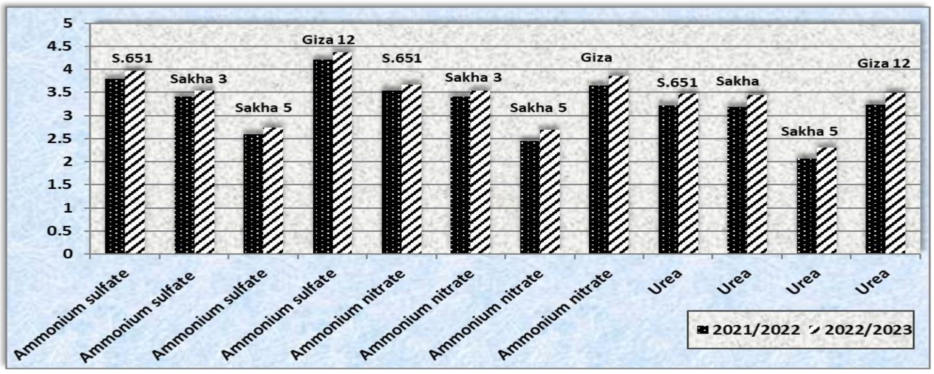

Figure 1. Influence of the interaction between nitrogen fertilizer sources and flax genotypes on straw yield/fed during the 2021/2022 and 2022/2023 seasons.

Seed yield and its features:

Throughout both experiment seasons, significant variations were noted in the fruiting zone length, number of capsules/plant, seed yield/plant and also seed yield/fed amongst nitrogen fertilizer sources treatments (Tables 4 and 5). It was observed that the use of ammonium sulfate treatment gained the best outcomes for the mentioned characteristics; fruiting zone length, number of capsules/plant, seed yield/plant and seed yield/fed followed by ammonium nitrate treatment. It is noted that there were no significant differences between the use of the ammonium sulfate or the ammonium nitrate treatments on those traits mentioned during both seasons, except seed yield/plant trait. While the application of urea treatment yielded the lowest values for the mentioned characters during the 1st and 2nd seasons. The increase in seed yield and its features with the use of ammonium sulfate compared to urea could be attributed to the low nitrogen absorption from urea and also the low nitrogen volatilization from soils with ammonium sulfate. Whatever the soil type, ammonia volatilization can pose a serious threat to urea supplies, but ammonium sulfate is resistant to this kind of nitrogen loss. These results align with those published by Buresh and De Datta (1990), Bijay and Yadvinder (2003), Hafez and Kobata (2012), Yasin *et al*. (2012), Abd Eldaiem and El-Borhamy (2015), El Mantawy (2017) and Emam (2019).

Tables 4 and 5 illustrate how the genotypes of flax (S.651, Sakha 3, Sakha 5 and Giza 12) that were evaluated had a significant impact on each season's fruiting zone length, number of capsules/plant, seed index, seed yield/plant, and also seed yield/fed. The obtained results showed that Giza 12 dual type genotype provided the best values for fruiting zone length, seed index and seed yield/plant, followed by Sakha 5 oil type genotype. However, Sakha 5 genotype attained the best values for number of capsules/plant and seed yield/fed over both agronomic seasons. Concurrently, S.651 (the fiber type strain) produced the lowest values of seed yield and related characteristics through each season (Tables 4 and 5). Most of the variation between flax genotypes can be explained by genetic factors between fiber, oil and dual types as a result of the difference in composition of the flax varieties studied. These outcomes concur with those mentioned by Elayan *et al.* (2018), Leilah *et al.* (2018), Kushwaha *et al.* (2019), Omar *et al.* (2020), Rashwan *et al.* (2020), Omar *et al.* (2021), Elsorady *et al.* (2022), Mahmoud *et al.* (2022) and Abdelmasieh *et al.* (2023).

Table 4. Fruiting zone length, number of capsules/plant and seed index of flax as influenced by nitrogen fertilizer sources and flax genotypes, furthermore their interaction during the 2021/2022 and 2022/2023 seasons.

Characters / Treatments		Fruiting zone length (cm) 2021/2022	Fruiting zone length (cm) 2022/2023	Number of capsules /plant 2021/2022	Number of capsules /plant 2022/2023	Seed index (g) 2021/2022	Seed index (g) 2022/2023
Nitrogen fertilizer sources:							
Ammonium sulfate		14.0	14.7	14.2	14.6	6.29	6.51
Ammonium nitrate		13.6	13.9	13.7	14.1	6.20	6.35
Urea		13.1	13.4	13.1	13.5	6.10	6.23
LSD at 5 %		0.6	0.9	0.6	0.6	NS	NS
Flax genotypes:							
S.651		6.5	6.7	6.1	6.6	3.12	3.33
Sakha 3		9.1	9.8	10.3	10.7	5.43	5.54
Sakha 5		18.9	19.3	19.3	19.9	7.04	7.17
Giza 12		19.7	20.0	18.9	19.1	9.19	9.42
LSD at 5 %		1.8	1.9	1.8	1.1	0.58	0.64
Interaction:							
Ammonium sulfate	S.651	6.8	7.3	6.5	7.0	3.21	3.48
	Sakha 3	9.7	10.4	11.1	11.1	5.53	5.69
	Sakha 5	19.2	20.0	19.8	20.5	7.11	7.32
	Giza 12	20.2	20.9	19.3	19.7	9.32	9.54
Ammonium nitrate	S.651	6.5	6.7	6.0	6.6	3.14	3.29
	Sakha 3	9.4	9.8	10.4	10.8	5.46	5.55
	Sakha 5	18.7	19.1	19.4	19.8	7.01	7.15
	Giza 12	19.6	19.9	18.9	19.1	9.19	9.40
Urea	S.651	6.1	6.1	5.6	6.1	3.02	3.21
	Sakha 3	8.3	9.2	9.5	10.3	5.31	5.37
	Sakha 5	18.7	18.9	18.7	19.3	7.01	7.04
	Giza 12	19.3	19.4	18.5	18.4	9.05	9.31
LSD at 5 %		NS	NS	NS	NS	NS	NS

Table 5. Seed yield/plant, seed yield/fed, oil percentage and oil yield/fed of flax as influenced by nitrogen fertilizer sources and flax genotypes, furthermore their interaction during the 2021/2022 and 2022/2023 seasons.

Characters / Treatments		Seed yield/plant (g) 021/2022	Seed yield/plant (g) 2022/2023	Seed yield (kg/fed) 2021/2022	Seed yield (kg/fed) 2022/2023	Oil percentage (%) 2021/2022	Oil percentage (%) 2022/2023	Oil yield (kg/fed) 2021/2022	Oil yield (kg/fed) 2022/2023
Nitrogen fertilizer sources:									
Ammonium sulfate		0.83	0.93	513.68	542.83	37.0	37.4	195.82	208.47
Ammonium nitrate		0.64	0.71	475.95	524.66	36.5	36.8	178.91	198.28
Urea		0.60	0.68	404.53	473.13	36.0	35.9	149.61	174.64
LSD at 5 %		0.18	0.19	43.26	31.40	NS	NS	16.40	10.61
Flax genotypes:									
S.651		0.43	0.52	342.34	396.13	33.4	33.6	114.35	133.14
Sakha 3		0.51	0.58	379.73	420.93	30.0	30.9	114.10	129.98
Sakha 5		0.88	0.96	615.52	682.01	43.6	43.5	268.02	296.77
Giza 12		0.94	1.03	521.30	555.09	38.8	38.7	202.64	215.30
LSD at 5 %		0.06	0.07	34.47	25.48	2.9	2.1	15.88	12.55
Interaction:									
Ammonium sulfate	S.651	0.51	0.64	371.88	422.27	33.9	34.1	125.62	143.68
	Sakha 3	0.57	0.66	407.50	439.01	31.0	31.6	125.88	140.01
	Sakha 5	1.05	1.11	701.89	708.43	43.7	43.9	306.39	311.11
	Giza 12	1.19	1.31	573.45	601.60	39.4	39.8	225.39	239.10
Ammonium nitrate	S.651	0.41	0.48	352.85	394.39	33.4	33.6	117.77	132.50
	Sakha 3	0.50	0.56	395.49	426.19	29.6	30.8	117.40	130.14
	Sakha 5	0.81	0.89	642.76	687.23	44.3	43.6	282.49	299.45
	Giza 12	0.83	0.93	512.68	590.85	38.7	39.1	197.96	231.01
Urea	S.651	0.38	0.46	302.29	371.73	33.0	33.1	99.67	123.22
	Sakha 3	0.45	0.53	336.19	397.60	29.4	30.1	99.02	119.80
	Sakha 5	0.78	0.88	501.90	650.38	43.0	43.0	215.19	279.76
	Giza 12	0.79	0.84	477.76	472.82	38.4	37.3	184.57	175.77
LSD at 5 %		0.10	0.11	59.71	44.13	NS	NS	27.51	21.73

Concerning the interaction impact between nitrogen fertilizer sources and flax genotypes, Table 5 and Figure 2 revealed that, throughout both seasons, the interaction had a significant impact on seed yield/plant and seed yield/fed. Data showed that applying ammonium sulfate treatment to Giza 12 and Sakha 5 flax genotypes, respectively, produced the highest values of seed yield/plant and seed yield/fed characteristics. As for seed yield/fed, there were no significant differences between fertilization with ammonium sulfate or ammonium nitrate with Sakha 5 genotype. Whilst, the application of urea treatment with S.651 flax strain resulted in the lowest seed yield/plant and seed yield/fed, respectively over both seasons of study.

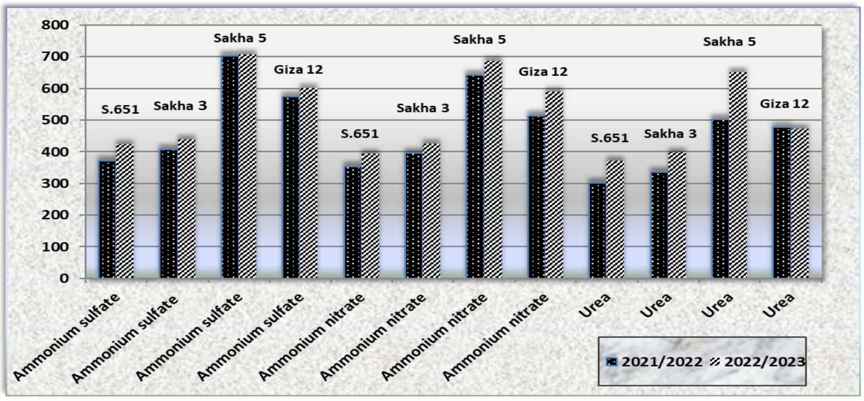

Figure 2. Influence of the interaction between nitrogen fertilizer sources and flax genotypes on seed yield/fed during the 2021/2022 and 2022/2023 seasons.

Oil yield and its features:

The studied nitrogen fertilizer sources treatments proved a significant effect on oil yield/fed only (Table 5). From the showed data, ammonium sulfate treatment achieved the highest values for the mentioned studied character in 1st and 2nd seasons, without any significant differences with ammonium nitrate treatment. While the lowest values obtained from this trait mentioned belonged to urea treatment in both seasons of the study. The use of ammonium sulfate has been found to increase oil yield because it plays a promoter role in the synthesis of proteins, oil content of seeds, through the amino acid creation of methionine (21% S) and cysteine (27% S). Additionally, sulfur plays a crucial role in oil crops since it is a component of acetyl Co-A, which is changed into maloyl Co-A during the fatty acid production process, involving the enzyme thiokinase. These findings are matched with those obtained by Buresh and De Datta (1990), Bijay and Yadvinder (2003), Jamal *et al.* (2010), Hafez and Kobata (2012), Yasin *et al*. (2012), Rasool *et al.* (2013), Abd Eldaiem and El-Borhamy (2015), El Mantawy (2017) and Emam (2019).

In terms of oil percentage and oil yield/fed, statistical analysis revealed extremely significant variations between the four genotypes of flax (Table 5). Data presented in Table 5 indicated that Sakha 5 the oil type cultivar has the highest oil percentage and oil yield/fed values subsequently by Giza 12 the dual type cultivar. Conversely, the lowest oil percentage and oil yield/fed values were obtained by Sakha 3 genotype the fiber type cultivar in both seasons. These findings might be explained by the fact that, oil types typically surpassed dual and fiber types in oil yield per feddan due to its genetic potential and higher percentage of oil. These results are in accordance with those obtained by Kineber *et al.* (2015), Leilah *et al.* (2018), Kushwaha *et al.* (2019), Omar *et al.* (2020), Rashwan *et al.* (2020), Omar *et al.* (2021), Elsorady *et al.* (2022), Mahmoud *et al.* (2022) and Abdelmasieh *et al.* (2023).

As for the interaction impact between nitrogen fertilizer sources and flax genotypes, Table 5 and Figure 3 revealed that interaction had a significant impact on oil yield/fed throughout the first and second seasons of study. Data indicated that the maximum values of oil yield/fed character were accomplished by ammonium sulfate treatment with Sakha 5 flax genotype and without any significant differences with ammonium nitrate treatment, whereas using urea treatment with Sakha 3 flax genotype during both seasons produced the lowest oil yield/fed.

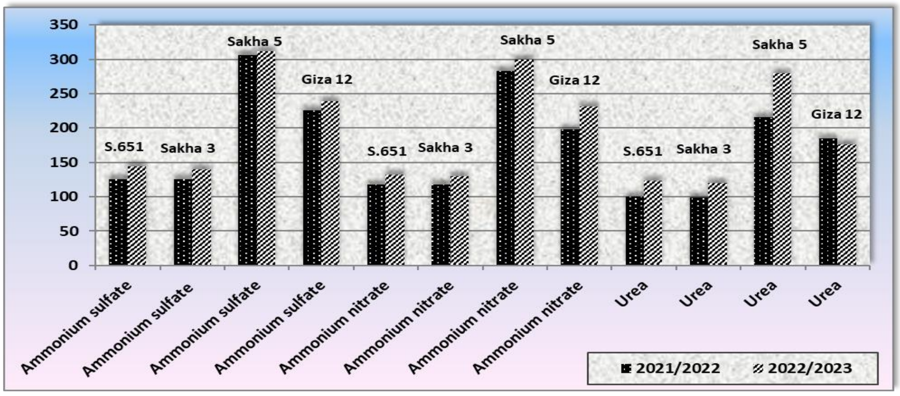

Figure 3. Influence of the interaction between nitrogen fertilizer sources and flax genotypes on oil yield/fed during the 2021/2022 and 2022/2023 seasons.

Fiber yield and its features:

The influence of various studied nitrogen fertilizer sources treatments on fiber yield and its features of flax are presented in Table 6. Application of ammonium sulfate treatment resulted in significant increases for fiber length, and fiber yield/fed followed by ammonium nitrate without any significant differences between them. Table 6 also showed that the application of urea treatment gave the lowest results for mentioned characters; fiber length and fiber yield/fed within both seasons of study. These results are mostly attributable to the appropriate nitrogen source, which in turn leads to increased nitrogen absorption, which is reflected in improved flax growth parameters like plant height and technical length. Concurrently, at the crucial stage of flax plant growth, nitrogen has a positive effect on individual fiber units, improving both the quality and amount of fiber produced. These results matched with those of Buresh and De Datta (1990), Bijay and Yadvinder (2003), Hafez and Kobata (2012), Yasin *et al.* (2012), Abd Eldaiem and El-Borhamy (2015), El Mantawy (2017) and Emam (2019).

Table 6 indicates significant effects of flax genotypes on fiber length, fiber percentage and also fiber yield/fed over both seasons. The presented data indicated that the new promising fiber strain (S.651) achieved significantly the best values for aforementioned characters compared to other cultivars through both seasons of study. While, the oil type Sakha 5 occupied the last place in those studied characteristics. These findings are primarily attributable to the fiber genotypes' genetic potential, which generally outperformed dual and oil types in terms of fiber length, fineness, percentage, and yield per feddan. These results align with those obtained by Elayan *et al.* (2018), Leilah *et al.* (2018), Kushwaha *et al.* (2019), Omar *et al.* (2020), Rashwan *et al.* (2020), Omar *et al.* (2021), Elsorady *et al.* (2022), Mahmoud *et al.* (2022) and Abdelmasieh *et al.* (2023).

Table 6. Fiber length, percentage and yield/fed of flax as influenced by nitrogen fertilizer sources and flax genotypes, furthermore their interaction during the 2021/2022 and 2022/2023 seasons.

Characters Treatments		Fiber length (cm)		Fiber percentage (%)		Fiber yield (kg/fed)	
		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Nitrogen fertilizer sources:							
Ammonium sulfate		76.9	78.9	17.3	17.8	342.53	373.22
Ammonium nitrate		72.6	73.4	16.7	17.2	322.02	349.69
Urea		69.2	71.2	16.4	16.6	281.56	309.73
LSD at 5 %		4.0	5.9	NS	NS	27.58	29.55
Flax genotypes:							
S.651		81.1	82.2	19.5	20.2	452.81	481.97
Sakha 3		76.0	78.1	18.6	18.9	353.19	381.85
Sakha 5		60.7	62.5	12.4	12.9	134.90	164.05
Giza 12		73.8	75.2	16.8	16.8	320.58	348.99
LSD at 5 %		6.5	9.0	1.3	1.1	18.20	24.53
Interaction:							
Ammonium sulfate	S.651	85.7	87.0	20.1	20.9	497.36	534.01
	Sakha 3	79.9	82.2	19.0	19.4	379.37	412.82
	Sakha 5	63.3	65.3	12.7	13.4	143.07	173.08
	Giza 12	78.9	81.0	17.4	17.6	350.31	372.98
Ammonium nitrate	S.651	80.2	80.9	19.5	20.3	468.94	498.68
	Sakha 3	76.5	77.6	18.6	18.9	357.18	389.24
	Sakha 5	60.7	61.6	12.4	12.8	138.86	160.97
	Giza 12	72.9	73.7	16.6	16.8	323.09	349.88
Urea	S.651	77.4	78.6	19.0	19.4	392.12	413.22
	Sakha 3	71.7	74.4	18.2	18.4	323.02	343.48
	Sakha 5	58.2	60.6	12.2	12.5	122.77	158.11
	Giza 12	69.6	71.1	16.3	16.1	288.34	324.11
LSD at 5 %		NS	NS	NS	NS	31.52	42.49

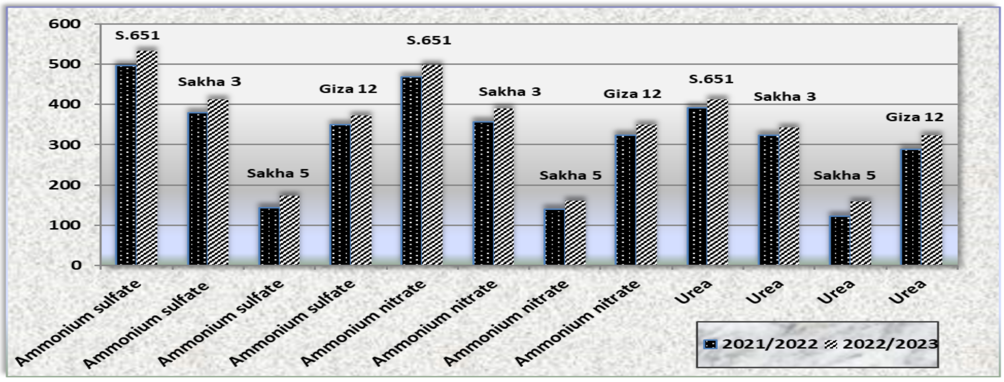

Figure 4. Influence of the interaction between nitrogen fertilizer sources and flax genotypes on fiber yield/fed during the 2021/2022 and 2022/2023 seasons.

Regarding the influence of the interaction between nitrogen fertilizer sources and flax genotypes, the obtained data shown in Table 6 and Figure 4 showed that interaction had a significant impact on fiber yield/fed during both seasons of study. The results showed that when ammonium sulfate or ammonium nitrate was used to fertilize the strain (S.651), the highest values of fiber yield/fed were achieved, without any significant differences between these two treatments throughout the 1st and 2nd seasons. While, fertilizing Sakha 5 cultivar with urea recorded the lowest values of aforementioned character.

CONCLUSION

In conclusion, the results of this experiment suggest that, in the Northern Delta of Egypt, ammonium sulfate or ammonium nitrate should be used as a nitrogen fertilizer source in conjunction with the new promising fiber type strain (S.651) for the best fiber yield/fed or with the oil type Sakha 5 cultivar for the best seed and oil yield/fed.

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تقييم بعض التراكيب الوراثية من الكتان تحت مصادر مختلفة من السماد الأزوتى

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الملخص

تم إجراء تجربتين حقليتين خلال موسمي شتاء ٢٠٢٢/٢٠٢١ و٢٠٢٣/٢٠٢٢ بالمزرعة البحثية بمحطة البحوث الزراعية بسخا بمصر , وذلك لتقييم أداء بعض تراكيب الكتان الوراثية (سلالة ٦٥١ , سخا ٣ , سخا ٥ وجيزة ١٢) تحت مصادر مختلفة من الأسمدة النيتروجينية وهى:- سلفات الأمونيوم (٢٠,٦% نيتروجين) ، نترات الأمونيوم (٣٣,٥% نيتروجين) واليوريا (٤٦,٥% نيتروجين). تم تصميم التجربة بأستخدام تصميم القطع المنشقة مرة واحدة فى أربعة مكررات. تم تخصيص القطع الرئيسية لمصادر الأسمدة النيتروجينية الثلاثة وتخصيص القطع الشقية للتراكيب الوراثية الأربعة للكتان. أشارت النتائج إلى أن استخدام معاملة سلفات الأمونيوم قد حقق معنوياً أعلى القيم في معظم الصفات المدروسة يليها نترات الأمونيوم ، في حين سجل استخدام اليوريا أقل القيم خلال كلا الموسمين . كما أشارت النتائج إلى تفوق السلالة ٦٥١ معنوياً على بقية التراكيب الوراثية الأخرى في صفات الطول الفعال وطول الألياف ونسبتها المئوية وكذلك محصول الألياف/فدان خلال كلا الموسمين . بينما سجل الصنف جيزة ١٢ أفضل النتائج وتفوق معنوياً على بقية الأصناف في صفات قطر الساق، محصول القش/نبات، محصول القش/فدان، طول المنطقة الثمرية، دليل البذرة، محصول البذور/نبات في كلا الموسمين. كما تفوق الصنف سخا ٥ معنوياً على التراكيب الوراثية الأخرى في عدد الكبسولات/نبات، محصول البذور/فدان، النسبة المئوية لمحتوى الزيت، محصول الزيت/فدان في كلا الموسمين. وعليه توصى هذه الدراسة باستخدام مصدر السماد النتروجيني سلفات الأمونيوم أو نترات الأمونيوم مع السلالة الواعدة S.651 للحصول على أعلى محصول ألياف/فدان، أو مع الصنف الزيتى سخا ٥ للحصول على أعلى محصول من البذور والزيت/فدان وذلك فى منطقة شمال الدلتا في مصر.