

Responses of Flax Genotypes (*Linum usitatissimum* L.) to Humic acid and Nano NPK Fertilizer on Yield, Oil Content, and Fatty Acid Content.

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Abstract

A field experiment was conducted during the 2023–2024 growing season at the College of Agriculture, Tikrit University at latitude (36.34°) North and longitude (41.43°) East to study the effect of adding humic fertilizer and nano NPK compound fertilizer, both individually and in combination, on grain yield, oil content, and some fatty acid components of several flax genotypes. The experiment was conducted using a randomized complete block design (RCBD) with three replications and four fertilizer treatments. The results showed significant differences between varieties, fertilization treatments, and interactions in the studied traits. The Polish variety exhibited the highest grain yield for linoleic acid. The interactions between varieties and fertilizer treatments showed significant effects, highlighting the importance of the interplay between genetic traits and mineral nutrition in improving the quantity and quality of oil in flax.

Key words: Flax, organic and nano-fertilizer, oil content, fatty acids.

Introduction:

Flax (*Linum usitatissimum* L.) is one of the most important oilseed crops in the world. It is cultivated in many countries to produce oil and fiber, due to its high content of unsaturated fatty acids, especially linolenic acid, which is essential for human health. It also contains varying proportions of oleic and linoleic acids, giving the oil high nutritional and industrial value [1]. Flax seeds are also a rich source of protein and minerals, which has given this crop a distinguished position among oilseed crops [2]. Improving flax productivity and oil quality depends on the plant's nutritional balance and nutrient absorption efficiency. Humic acid is one of the most important natural organic compounds that contribute to improving soil properties and increasing the availability of nutrients to plants [3]. Furthermore, NPK nano-composite fertilizers are among the latest trends in fertilization management due to their small particle size and ease of absorption, which increases

nutrient utilization efficiency and reduces losses [4]. Combining humic acid with nano-fertilizers represents a promising approach to achieving integrated plant nutrition, combining the high biological efficiency of nanoparticles with the improving effect of humic acid on soil fertility and plant growth [5]. However, the response of flax genotypes to these treatments may vary depending on their genetic characteristics [5]. Hence, the importance of this study, which aims to evaluate the effect of adding humic acid and NPK nano-composite fertilizer on grain yield, oil content, and fatty acid content (linolenic, oleic, and linoleic) in several flax genotypes, with the goal of identifying the most efficient fertilizer treatment and varieties under local growing conditions in Iraq. This study aims to evaluate the effect of adding humic acid and NPK nano-composite fertilizer on grain yield, oil content, and fatty acid content (linolenic, oleic, and linoleic) in several flax genotypes, in order to determine the most efficient fertilizer

treatment and varieties under local growing conditions in Iraq.

Materials and Methods

The experiment was conducted at the Field Crops Research Station of the College of Agriculture, Tikrit University, during the 2023–2024 growing season. The field soil moderates physical and chemical properties and had not been planted with fertilized crops in the previous season. The land was prepared by plowing and leveling, and a drip irrigation system was installed with planting distances of 0.4 m between rows and 0.1 m between emitters. The experiment involved studying two factors, the first was fertilization, and the second included nine varieties, the randomized complete block design (RCBD) were used in this experiment with three replications. The fertilization (first factor) included four treatments:

1-Without fertilization (control)

2-Humic acid at a rate of 8 ($^{-1}$ kg h)

3-NPK nano-compound fertilizer (20-20-20) at a concentration of 0.75 g L $^{-1}$

4 -Humic acid + NPK nano-compound

Nine flax genotypes (Sakha1, Sakha3, Sakha4, Sakha5, Sakha6, Linata, Sharda, Polish, Giza10), as shown in Table 1, were used and planted according to the recommended spacing . All necessary agricultural practices, including irrigation and weed and pest control, were implemented. Statistical analysis of the data was performed according to the experimental design using the SAS software package. The values traits studied were compared using Duncan's Multiple Range Test at a significant level of 5%. The traits were measured after the full maturity stag, the studied traits included grain yield (kg ha $^{-1}$), oil content (%), and fatty acid content (linolenic, oleic, and linoleic %). Oil content and fatty acid extraction were measured in the laboratories of the Food Science Department, College of Agriculture, Tikrit University, using the Soxhlet extraction method [18]. Fatty acid composition was analyzed using gas chromatography (GC).

Table (1) lists the varieties used in the study, their origin, and their lineage.

lineage	Source	Flower color: Purple	Origin	Genetic structures
I.1485 x Bombay	College of Agriculture – Cairo University	Purple	Egyptian	Sakha1
Belinka (2E) × I.2096	College of Agriculture – Cairo University	White	Egyptian	Sakha3
Importer	College of Agriculture – Cairo University	Purple	Egyptian	Sakha4
)Belinka (R3) × 1.2569	College of Agriculture - Salahaddin University	Purple	Egyptian	Sakha5
S.420 x ombay (I. USA)	College of Agriculture – Cairo University	Purple	Syrian	Sakha6
)Giza6 × Senta Catalina	College of Agriculture – Cairo University	White	Indian	Linata

Importer	College of Agriculture - Salahaddin University	Purple	Polish	Sharda
Importer	College of Agriculture – Cairo University	White	Egyptian	Bolsh
S.420/140/5/10 × Bombay	Source	Flower color: Purple	Origin	Giza 10

Soil analysis was carried out in the laboratories of the Soil and Water Resources Department at the College of Agriculture, Tikrit University, to determine the physical, chemical, and properties present in the soil, as shown in Table (2).

Table (2): Analysis of the physical, chemical, and biological properties of the gypsiferous field soil.

values	Unit	traits
7.6	-	(PH) pH
15.5	centimol.kg-1	(CEC) Cation Exchange Capacity
0.6	g.kg-1	(O.M) Organic Matter
162		(CaSO4) Gypsum
180		(CaCO3) Lime
21	mg.kg-1	(N) Available Nitrogen
4.5		(P) Available Phosphorus
116		(K) Available Potassium
1.24	g.cm-3	(BD) Bulk Density
106x6.8	g ⁻¹ Soil CFU	Total Bacteria
103x12		Total Fungi

Results and Discussion:

1- Grain Yield (¹kg h)

The results in Table (3) showed significant differences between the varieties in grain

yield, as the variety Polish had the highest production of (979.13 kg h⁻¹), followed by Giza 10 with an average of 903.97 kg. ha⁻¹, while the Sakha 3 variety recorded the lowest value (743.40 (¹kg h)

This variation is attributed to genetic differences in metabolic efficiency, as noted by [6], who confirmed the existence of clear genetic variation in flax production traits. Regarding fertilization treatments, the humic + nano-fertilizer treatment achieved the highest average yield ($1121.39 \text{ (}^{-1}\text{kg h)}$)

compared to the lowest value in control treatment ($639.21 \text{ (}^{-1}\text{kg h)}$)

This is explained by the role of humic acid in improving nutrient uptake and increasing plant metabolic activity, in addition to the

effectiveness of nano-fertilizer in enhancing nutrient utilization efficiency. [7] confirmed that combining organic and nano-fertilizers contributes to improved uptake efficiency and increased yield. The interaction of Polish \times Humic + Nano resulted in the highest yield ($1419.83 \text{ (}^{-1}\text{kg h)}$)

while the lowest was in Sakha3 \times control ($569.63 \text{ (}^{-1}\text{kg h)}$)

demonstrating that the interaction between genetic factors and fertilization is a crucial factor in determining flax productivity [8].

Table (3): The effect of fertilizers, varietal differences, and their interaction on grain yield (kg ha^{-1})

Average varieties	Fertilizer additives				Varieties
	Humic fertilizer + Nano	Nano fertilizer	Humic fertilizer	control	
774.8 c	1101.07 cde	664.52 hij	797.91 f-i	625.81 ij	Sakha 1
743.40 c	967.41 def	714.66 hij	721.90 hij	569.63 j	Sakha 3
830.60 bc	1218.21 b	732.82 hij	743.74 g-j	627.62 ij	Sakha 4
780.66 c	1019.56 cd	710.84 hij	789.17 f-i	603.08 j	Sakha 5
834.58 bc	1190.27 bc	746.75 g-j	798.58 f-i	602.69 j	Sakha 6
764.26 c	109.10 cde	685.39 hij	731.87 hij	630.68 ij	Linata
754.72 c	1005.6 de	686.14 hij	695.30 hij	632.37 ij	Sharda
979.13 a	1419.83 a	843.83 d-h	926.21 d-g	726.66 hij	Polish
903.97 ab	1252.00 ab	801.79 f-i	827.78 e-h	734.32 hij	Giza 10
	1121.39 a	731.86 bc	781.39 b	639.21 c	Average Fertilizers

2- Fixed oil Percentage in Seeds %

The results in Table (4) show significant differences between the genotypes in oil percentage. The Sakha 5 variety had the highest average (36.67%), followed by Linata (36.37%) and Giza 10 (35.71%). The lowest values were for the Sakha 4 (35.41%) and Sharda (35.33%) varieties. This variation is attributed to genetic differences between the

genotypes in the efficiency of oil formation and accumulation within the seeds, as indicated in [9]. As for the fertilizer treatments, the nano-fertilizer treatment achieved the highest average (36.67%), followed by the humic + nano-fertilizer treatment (36.44%), then the control treatment (35.19%). The lowest values were for the humic acid treatment alone (34.54%). This is explained by the role of nano-fertilizers in

enhancing nutrient absorption and stimulating the formation of carbohydrate compounds involved in oil synthesis, as demonstrated in [10]. In the interactions, the highest oil percentage was recorded in the Giza 10 × nano-fertilizer variety (38.11%), followed by Sakha 5 × humic + nano-fertilizer (37.97%) and Sakha 1 × humic + nano-fertilizer (37.39%). Conversely, the percentage

decreased in Sakha 3 × control (33.46%) and Giza 10 × control (33.31%). These results indicate that the response of varieties to fertilizer treatments varies according to their genetic makeup, a finding corroborated by [11], which demonstrated that combining organic and nano-fertilizers enhances oil accumulation in flax.

Table (4): The effect of fertilizers, varietal differences, and their interaction on seed oil percentage

Average varieties	Fertilizer additives				cultivars
	Humic fertilizer +Nano	Nano fertilizer	Humic fertilizer	control	
36.67 a	37.39 abc	36.50 a-d	32.15 i	36.46 a-d	Sakha 1
35.45 a	35.25 a-h	37.55 ab	35.56 a-h	33.46 e-i	Sakha 3
35.41 a	34.20 d-i	36.60 a-d	36.30 a-e	34.50 c-i	Sakha 4
36.67 a	37.97 a	36.28 a-e	35.24 a-h	37.21 abc	Sakha 5
35.46 a	37.19 abc	37.40 abc	32.66 hi	34.57 c-i	Sakha 6
36.37 a	35.45 a-h	37.32 ab	37.16 a-d	35.55 a-h	Linata
35.33 a	36.68 a-d	34.58 c-i	34.21 d-i	35.86 a-f	Sharda
35.31 a	37.24 abc	35.63 a-g	32.76 ghi	35.62 a-h	Polish
35.71 a	36.60 a-d	38.11 a	34.84 b-i	33.31 f-i	Giza 10

	36.44 a	36.67 a	34.54 b	35.19 ab	Average Fertilizers
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3- Linolenic Acid

Table (5) shows that the Sharda variety had the highest linolenic acid content at 20.03%, while the Sakha 4 variety recorded the lowest value at 18.75%. This variation is attributed to genetic differences in oil composition and the percentage of unsaturated fatty acids in the seeds, as noted by [12] in his study of genetic variation in flax compositions.

Regarding the fertilizer treatments, the humic + nano treatment resulted in the highest average acid content at 19.84%, compared to the control treatment which recorded 18.99%.

This superiority is explained by the increased efficiency of photosynthesis and improved nutrient absorption, leading to increased accumulation of fatty acids in the seeds, which is consistent with the results of [13]. When combined, the Sakha 5 × humic + nano treatment had the highest content at 20.63%, while the lowest value was for Sakha 4 × the control (17.58%). These results indicate the importance of the interaction between genetic traits and fertilization factors in determining oil composition. [14] also emphasized the combined role of nano- and organic fertilization in increasing the percentage of unsaturated fatty acids in flax.

Table (5): Effect of humic acid and nano-NPK fertilizer combinations and their interaction, according to variety, on seed linolenic acid content

Average varieties	Fertilizer additives				cultivars
	Humic fertilizer + Nano	Nano fertilizer	Humic fertilizer	control	
18.98 cd	18.98 d-g	19.64 a-g	18.38 gh	18.93 d-g	Sakha 1
19.04 cd	19.33 c-f	19.01 d-g	19.10 d-g	18.71 gh	Sakha 3
18.75 d	19.62 a-g	19.04 d-g	18.74 fgh	17.58 h	Sakha 4
19.73 ab	20.63 ab	19.78 a-f	19.27 c-g	19.23 c-g	Sakha 5
19.78 ab	20.40 abc	19.94 a-f	19.78 a-f	19.02 d-g	Sakha 6

19.58 abc	20.21 a-d	19.85 a-f	18.88 efg	19.39 b-g	Linata
20.03 a	20.12 a-e	20.07 a-e	19.82 a-f	20.10 a-e	Sharda
19.17 bcd	19.58 a-g	19.23 c-g	18.85 e-h	19.04 d-g	Polish
19.60 abc	19.69 a-f	20.73 a	19.01 d-g	18.97 d-g	Giza 10
	19.84 a	19.70 a	19.09 b	18.99 b	Average Fertilizers

4- Oleic Acid

The results in Table (6) indicate clear differences between varieties in oleic acid content. The Giza 10 variety recorded the highest percentage at 18.51%, while the lowest value was in the Sakha 4 variety (15.88%). This difference is attributed to genetic variation in the fatty acid composition of the oil, as explained by [1] when evaluating the chemical properties of flaxseed oil. As for the fertilization treatments, the humic + nano treatment achieved the highest oleic acid content at 23.10%, compared to the control treatment which recorded 16.47%. This superiority is explained by the role of

integrated fertilization in improving physiological processes and increasing the accumulation of unsaturated fatty acids within the seeds, as indicated by [15]. In the interactions, the Polish \times Humic + Nano treatment gave the highest content at 26.42%, while the lowest value was in Sakha 3 \times the control (15.20%). These results confirm that the interaction of genetic factors with organic and nano-fertilizers contributes to improving oil quality. Furthermore, a study [16] demonstrated that integrated fertilization enhances the efficiency of beneficial fatty acid formation in flax seeds.

Table (6): Effect of humic and nano-NPK compound fertilizer combinations, varietal differences, and their interaction on seed oleic acid content

Average varieties	Fertilizer additives				cultivars
	Humic fertilizer +Nano	Nano fertilizer	Humic fertilizer	control	
17.02 b	23.30 bc	19.17 h-l	20.22 f-i	16.31 op	Sakha 1

17.10 a	20.45 e-h	17.26 mno	18.66 j-m	15.20 P	Sakha 3
15.88 c	22.89 bcd	18.25 Lmn	19.96 f-j	16.67 op	Sakha 4
17.10 b	21.43 def	19.31 h-l	19.84 f-j	16.14 op	Sakha 5
17.05 b	23.96 b	18.42 klm	20.48 e-h	16.57 op	Sakha 6
17.09 b	22.66 bcd	19.06 h-l	20.97 efg	16.83 no	Linata
16.92 b	23.39 b	18.75 i-m	20.08 f-j	16.37 op	Sharda
17.03 b	26.42 a	20.20 f-i	21.84 cde	17.46 mno	Polish
18.51 a	23.42 b	19.50 g-l	20.53 e-h	16.73 o	Giza 10
	23.10 a	18.88 b	20.29 b	16.47 c	Average Fertilizers

5-Linoleic acid

The results in Table (7) show significant differences between the varieties in linoleic acid content. The Giza 10 variety had the highest percentage at 18.51%, while the Sakha 4 variety recorded the lowest value at 15.88%. This variation is attributed to genetic differences in oil composition and the efficiency of fatty acid biosynthesis, as indicated in [17]. As for the fertilizer treatments, the humic + nano treatment showed the highest acid content at 20.65%, compared to the control treatment which recorded 13.76%. This is explained by the fact

that combining humic and nano fertilizer increases the availability of nutrients and stimulates oil formation within the seeds, leading to an increase in the percentage of fatty acids, as confirmed by the results in [7]. In the interaction, the Giza 10 × humic + nano treatment recorded the highest content at 23.52%, while the lowest value was for Sakha 4 × control (12.70%). These results demonstrate that the interaction between genetic factors and fertilization treatments plays a crucial role in improving oil quality and its components. This aligns with the findings of [4] regarding the impact of

integrated fertilization on enhancing the quality of vegetable oils.

Table (7): Effect of the arithmetic means of combinations of humic acid, nano-NPK compound fertilizer, varieties, and their interactions on the linoleic acid content of seeds.

Average varieties	Fertilizer additives				cultivars
	Humic fertilizer + Nano	Nano fertilizer	Humic fertilizer	control	
17.02 b	20.50 bc	15.91 ij	17.88 fg	13.78 l	Sakha 1
17.10 b	20.62 bc	15.84 ij	13.96 efg	13.97 kl	Sakha 3
15.88 c	18.90 de	14.97 kj	16.96 hg	12.70 m	Sakha 4
17.10 b	20.88 b	15.78 ij	17.82 fg	13.92 l	Sakha 5
17.05 b	20.15 bc	15.85 ij	18.25 ef	13.94 l	Sakha 6
17.09 b	20.72 bc	16.18 hi	17.80 fg	13.69 ml	Linata
16,92 b	19.81 cd	16.17 hi	17.72 fg	14.00 kl	Sharda
17.03 b	20.77 bc	15.97 hij	17.72 fg	13.68 ml	Polish
18.51 a	23.52 a	17.47 fg	18.92 de	14.15 kl	Giza 10
	20.65 a	16.01 c	17.89 b	13.76 d	Average Fertilizers

Conclusions

The study revealed a clear variation among flax varieties in the traits studied. The Polish variety excelled in grain yield, Linata was distinguished by its oil content, while Sharda and Giza 10 exhibited the highest fatty acid content. Furthermore, the humic acid + nano-treatment proved effective in increasing yield and improving oil quality compared to the other treatments. This treatment is considered one of the most successful integrated fertilization methods for increasing flax productivity and oil quality under local growing conditions.

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