IMPACT OF NANO AND MINERAL FERTILIZERS ON QUALITY AND MEDICAL PROPERTIES OF FLAX OIL

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ABSTRACT

Two field factorial experiments were carried out at (Grda-rasha and Grdmala) fields in Erbil Governorate - Kurdistan Region-Iraq during the growing season of 2019-2020. This study was aimed to evaluate the effects of Nano and mineral fertilizers on quality and some medical properties of two flaxseed oil (*Linum usitatissimum* L.) cultivars with a randomized complete block design using 3 replicates. The first factor included seven fertilization treatments (control, Kcl, Urea, Agriculture Sulfur, Triple Super Phosphate, Super Nano-fertilizer, and Nano-NPK), the second factor was Libra and Brazowe flax cultivars. The fertilizer treatments significantly affected natural product properties. The highest value of mucilage (30.70 and 39.26 %) were produced from application of urea and Nano NPK, moreover the highest value of antioxidant activity (75.30 and 86.53 %) was produced from the application of super Nano and triple super phosphate for both locations respectively. The cultivars affected significantly on most of the studied characteristic, the highest mucilage, phenol content and antioxidant activity were produced from the Brazowe cultivar at Grdmala. Application of Nano NPK caused a significant increase in linolenic acid concentration at both locations, which were reached to (39.10 and 37.35 %) respectively. The highest value of oil (33.42 %) had produced from interaction treatments of (Brazowe x Nano NPK) while mucilage, and linolenic were obtained from interaction treatments of (Libra x Nano NPK) with the values of (40.48 and 39.40 %), respectively.

Keyword: nano fertilizer, inorganic fertilizers, cultivars, flax oil seed, therapeutic constituent.
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تأثير الأسمدة النانوية والمعدنية على الجودة والخصائص الطبية لزيت الكتان

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المستخلص

اجريت تجربتين عاملية فى موقعين (كرد ملا و كرده ره ش) الواقعة ضمن محافظة اربيل – اقليم كردستان العراق خلال الموسم الزراعى 2019–2020. تهدف هذه الدراسة تقييم تاثير السماد النانوي و المعدنى على صفات النوعية و بعض الخصائص الطبية فى زيت صنفين من الكتان الزيتى (*Linum usitatissimum* L) و باستخدام تصميم القطاعات الكاملة العشوائية بثلاث مكررات. العامل الاول تضمنت سبع معاملات سمادية وهى (معاملة المقارنة، كلوريد البوتاسيوم، اليوريا، الكبريت الزراعى، سوبر فوسفات الثلاثى، سوبر نانو و NPK النانوى) والعامل الثانى صنفين من كتان البذور (Libra و Brazowe). المعاملات السمادية اثرت معنويا على صفات المنتجات الطبيعية فى زيت الكتان ،حيث سجلت اعلى قيمة للالياف الذائبة (mucilage) 30.70 و 39.26) % من معاملتى اليوريا و NPK النانوى، علاوة على ذلك كانت اعلى قيمة لمضادات الاكسدة (75.30 و86.53) % والتى سجلت من اضافة سوبر نانو و سوبر فوسفات الثلاثى لكلا الموقعين على التوالى . اثرت صنفى الكتان معنويا على معظم الصفات المدروسة، فكانت اعلى قيمة للالياف الذائبة ، الفينولات الكلية و مضادات الاكسدة مسجلة فى الصنف Brazowe فى كرد ملا . ان اضافة NPK النانوي اثرت معنويا فى تركيز الحامض العضوى Linoleic فى كلا الموقعين حيث سجلت (39.10 و 37.35) % على التوالى ، اما اعلى قيمة للزيت 33.42 %، دونت من المعاملة التداخلية بين (Brazowe *NPK النانويى) بينما الالياف الذائبة و الحامض العضوى (Linolenic) لوحظت فى المعاملة التداخلية (Libra *NPK النانويى) بقيم (40.41 و 39.40) % على التوالى .

الكلمات المفتاحية :السماد النانوي ، السماد غير العضوي ، الصنف ، زيت بذور الكتان ، المكونات العلاجية .
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INTRODUCTION

Flaxseed (*Linum usitatissmum*) is gaining importance in the world's food chain as a functional food due to more health benefits and the growing interest of consumers for foods. Flaxseed contains about 75 to 80 times more lignin's than cereal grains and other legumes, fruits, vegetables (22). Flax has recently gained attention as a functional food ingredient due to its rich potential health benefits associated with its biologically active components such as alpha-Linolenic acid, lignin's, and dietary fiber. (30) reported that the high Linolenic (C18:3) content of flaxseed makes the oil an excellent drying agent in paints, resins, inks, soaps, varnishes, wood treatment, linoleum, etc. Flaxseed mucilage is multi-branched hydrophilic substance, forming viscous solutions that delay gastric emptying and nutrient absorption from the small intestine (31). However, α - Linolenic acid in flaxseed can reduce the risk of cardiovascular disease, osteoporosis, rheumatoid arthritis, and cancer (3). NPK fertilizers are essential for increasing agricultural output (29). Especially with nano structure. Because it stimulates plant development and reduces pollution, this is seen as a great alternative to chemical fertilizers. Nano-fertilizers are made to release active components in response to biological and environmental demands (5) are nutrient carriers that are being developed using substrates with Nano dimensions of (1– 100 nm). Nano-fertilizers are very effective for providing nutrients throughout the crop growth period (12). Crop growth rate increase to optimum concentration by Nano- fertilizer but this increase in concentration could be inhibit the crop growth due to the toxicity of nutrient (35). As an alternative to traditional chemical fertilizer, to our surprise, only a few kinds of research are available on the beneficial effect of nanoparticles or Nano fertilizers on plant growth, yield, and quality. (7) concluded that Super Nano followed by Nano-NPK and Nano-Zinc and Nano Fe in two locations for leaf area, and head diameter leaf area index Since there are few studies about the effect of Nano fertilizers and its comparison with different types of traditional fertilizers on chemical composition of the flax plant, the current research was suggested to study the effect of Nano and mineral fertilizers impact on quality and medical properties of flaxseed Oil (*Linum usitatissimum* L.) cultivars at two different locations.

MATERIALS AND METHODS

A field experiment was conducted during winter growing season of (2019-2020) at two locations, the first one conducted at Grda-rasha, the research farm of Agricultural Engineering Sciences College, Salahaddin University- Erbil, with GPS reading of (Latitude 36. 10116 N and Longitude 44.00925 E), and elevation of 415 meters above sea level. The second location was Grdmala, with GPS reading of (latitude 36. 01061N, and longitude 44. 05854E) and elevation of 413.8 meters above sea level. The experiment was conducted under rain fed conditions and irrigated according to crop requirements. Numerous soil samples were taken from the upper 50 cm of the experimental field and combined to make a representative composite sample (Table, 1).

Table 1. Some physical and chemical properties of the studied soils before planting

Soil properties		Units	Grda-rasha	Grdmala
Particle distribution size	Sand	($g\ kg^{-1}$)	51.80	118
	Silt		480	432
	Clay		369.46	450
Soil texture			Silty clay loam	Silty clay
Soil pH			7.65	7.86
ECe		$dS\ m^{-1}$	0.60	0.50
Organic matter content		($g\ kg^{-1}$ soil)	11.77	9.76
Calcium carbonate			312.00	250
Total nitrogen		($mg\ g^{-1}$soil)	2.35	0.80
Available Phosphorous		($\mu g\ g^{-1}$ soil)	3.42	9.3
Soluble ions	Ca^{2+}	$mmol_c^{-1}$	1.99	2.50
	Mg^{2+}		1.88	1.55
	Na^{+}		0.72	0.95
	K^{+}		0.09	1.14
	HCO_3^{-}		3.22	3.50
	CO_3^{2-}		0	0
	Cl^{-}		1.07	2.3

A factorial experiment within randomized complete block design (RCBD) was used, using two factors, the first was the fertilization treatments which included:

1. Control spraying only distilled water.
2. Foliar spray of Super Nano-fertilizer which contain (6% N, 3% P, 17% K, 4% Fe, 4% Zn, 2% Mn, 0.5% Cu, 0.5% B, 0.1% Mo, 1% Ca, 3% Mg, and 6% S) at rate of (200 mg L^{-1})
3. Nano NPK (20:20:20) (Khazra Nano chelated) fertilizer (200 mg L^{-1}).
4. Agricultural Sulphur foliar application at the rate of (200 mg L^{-1}). The three application above applied at 50 % flowering stages.
5. Urea (160 kg ha^{-1}): The urea which equivalent to (24 g $plot^{-1}$) was applied in two doses. The first dose (12 g) was applied on 29th November 2019, while the second dose (12 g) applied at 5th March 2020, at both locations.
6. KCl (160 kg ha^{-1}): At the rate of (24 g $plot^{-1}$) applied during sowing time
7. Triple Super Phosphate (160 kg ha^{-1}): Applied at sowing time at rate of (24 g $plot^{-1}$).

The Second Factor was Flax Cultivars which are: 1- C_1= Libra: obtained from the research center of Bagdad. 2- C_2

Brazowe: obtained from Poland research center. The field was subdivided into three blocks' each block consists of 14 experimental units. The plot's dimensions were (1*1.5 m) which contains five row, the distances between them were 20 cm. The seeds were sown by hand on 11th November, 2019, at a rate of 24g for each plot, then simultaneously irrigated, hand weeding practiced as needed, the plants were harvested on 8th June 2020 by hand.

The quality measurement of flax seed

1- Chemical characteristics:

a. Oil content %: Oil % determination done using the Soxhlet apparatus for oil extraction as mentioned by the Association of Official Analytical Chemists (1).

b. Protein content %: The total nitrogen content was determined by the micro-Kjeldahl digestion method.

c. Phosphorus: was measured by the colorimetric method (V-1100 digital), as described by (15). A spectrophotometer at 410 nm was used.

d. Total potassium concentration: The total potassium was measured by the flame photometric (BWB Technologies), method (9). Protein percent was determined according to the equation described by (13) as follow: Protein % = N % x 6.25

2. Active substance in flax seed

a- Mucilage substances

b- Total phenol content using folin-ciocalteu reagent

C- Antioxidant activity

3. Fatty acids composition (%)

Unsaturated fatty acids

a. Oleic (C18:1)

b. Linoleic (C18:2) c. Linolenic acid (C18:3).

Statistical analysis

The data were statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design, (RCBD) using SPSS program version (24), the mean comparison was fulfilled according to Duncan's multiple range test (12) at the level of significant 0.05. The charts were drawn using Excel software package (4).

Cluster analysis

Cluster analysis was conducted between chemical components in flax cultivars using XILSTATE- premium program to obtain homogenous groups by agglomerative hierarchical clustering (AHC).

RESULTS AND DISCUSSIONS

1- Effect of fertilizer, cultivars, and their interactions on chemical characteristics

a- Oil percentage %: At Grdmala the presented data in the Table (2) shows that the studied factors and their interactions significantly influenced on oil percentage, the highest value was produced from the application of Triple Super Phosphate and Nano NPK with the mean value of 28.77 and 32.96 % respectively, and the lowest mean values were obtained from control treatments for both locations. This could be due to the role of phosphorus in oil formation. (19) reported that the highest seed oil % value 26.5 % was obtained from the application of 150 kg ha^{-1} N.P.K (10–15–10) fertilizers as the source of macro complete fertilizer. The results were in the same line with those obtained by (14). The effect of NPK fertilizer application was found to be significant on fatty acid compositions, oil%, and oil yield(31) .The

highest percentage of oil was observed at Grdmala in comparing with Grda-rasha, this could be due to the differences between the soil properties of the two locations (Table,1) or due to the difference between environmental data (Fig. 1). The oil % was also affected significantly by cultivars, the highest mean value 27.50 and 30.73 % was produced for the Brazowe cultivar, and the lowest value 25.93 and 29.95 % was noted for the Libra cultivar at both locations respectively. This could be due to the difference between their genetic properties. The higher seed oil % location compared with Grda-rasha location could be due to higher available phosphorus of Grdmala soil in comparing with available at Grda-rasha soil (Table, 1). This result similar to the result of (28). Similarly, noticed that the oil % was affected by the interaction treatments. The highest oil percentage values 30.18 and 33.42 % were produced from the interaction treatments of TSP x Libra and Nano NPK x Brazowe for Grda-rasha and Grdmala location, respectively. This could be due to the single effect of treatments contributed in interaction effect between fertilizer and cultivars.

Table 2. Effect of fertilizer treatments, cultivars, and their interactions on oil %.

Fertilizer treatments	Locations					
	Grda –rasha -L1			Grdmala-L2		
	Libra	Brazowe	Mean of Fertilizers	Libra	Brazowe	Mean of Fertilizers
Control	21.26^{b}	24.48^{ab}	22.87^{c}	27.76^{c}	27.79^{c}	27.77^{c}
KCl	25.60^{ab}	29.20^{a}	27.40^{ab}	30.05^{abc}	29.85^{abc}	29.95^{bc}
Urea	26.42^{ab}	28.71^{a}	27.56^{ab}	28.50^{bc}	32.65^{ab}	30.57^{ab}
Agriculture Sulfur	26.68^{ab}	27.89^{a}	27.29^{ab}	29.71^{abc}	32.22^{ab}	30.97^{ab}
Triple Super hosphate	30.18^{a}	27.35^{ab}	28.77^{a}	30.60^{abc}	28.95^{bc}	29.77^{bc}
Super Nano-fertilizer	25.02^{ab}	26.52^{ab}	25.77^{b}	32.21^{ab}	28.60^{bc}	30.40^{ab}
Nano NPK	26.32^{ab}	28.35^{a}	27.34^{ab}	32.50^{ab}	33.42^{a}	32.96^{a}
Mean of cultivars	25.93^{b}	27.50^{a}		29.95^{b}	30.73^{a}	

b- Protein Content %: Table 3, shows the protein content of two flax cultivars influenced significantly by soil application of urea. The highest and lowest mean values 23.15 and18.96 % was found from soil urea fertilizer application and control respectively. It means application of urea caused surprises 22.10 % of protein on control treatments at Grda-rasha field. This result is in line with those produced by (25) who reported that urea positively influenced on protein content. In contrast, the highest protein % at Grdmala was 23.83% that obtained by super Nano application, while the protein content did not affect significantly by cultivars in both locations. Furthermore, the results indicated to significant effect of interaction treatments on protein %. The highest values 23.30 and 25.46 % were Urea x Libra and Super Nano x Libra respectively, while the lowest values were found from Control x Brazowe for both locations respectively. These differences could be due to the genetic background of the cultivars and their behavior under conditions or fertilizers. These results were in harmony with (13).

These results agree with the result (8) indicated the significant effect of foliar application of Nano fertilizer types on protein yield. The highest values (1.14, 1.32, and 1.24) t ha^{-1} were recorded from Nano NPK for Ranya and Saruchawa and their averages. The lowest values (0.74, 0.72, and 0.73) tha^{-1} were observed from the Control treatments.

Table 3. Effect of fertilizer treatments, cultivars, and their interactions on protein %.

Fertilizer treatments	Locations					
	Grda-rasha-L1			Grdmala-L2		
	Libra	Brazowe	Mean of Fertilizers	Libra	Brazowe	Mean of Fertilizers
Control	19.13^{c}	18.78^{c}	18.96^{d}	19.49^{c}	19.28^{c}	19.39^{c}
KCl	22.73^{ab}	21.29^{abc}	22.01^{ab}	23.12^{abc}	20.95^{bc}	22.03^{ab}
Urea	23.30^{a}	22.99^{ab}	23.15^{a}	24.15^{ab}	23.33^{ab}	23.74^{a}
Agriculture Sulfur	20.55^{bc}	19.22^{c}	19.88^{cd}	20.88^{bc}	21.01^{bc}	20.94^{bc}
Triple Super Phosphate	21.19^{abc}	20.81^{abc}	21.00^{bc}	20.62^{bc}	21.28^{bc}	20.95^{bc}
Super Nano-fertilizer	20.71^{abc}	21.07^{abc}	20.89^{bc}	25.46^{a}	22.20^{bc}	23.83^{a}
Nano NPK	22.68^{ab}	22.49^{ab}	22.59^{ab}	22.78^{abc}	22.85^{abc}	22.82^{ab}
Mean of cultivars	21.47^{a}	20.95^{a}		22.36^{a}	21.47^{a}	

c- Phosphorus content %

Figure (1), illustrates that different fertilizers had significant effect on phosphorus content in flaxseed. The highest values 0.77 and 0.80 % were obtained from using triple super phosphate at Grda-rasha and Grdmala respectively, while the lowest value just about 0.37 % for both locations, additionally, Super Nano could cause to record the same value (0.80 %) in Grdmala. This results in agreement with (14) they found that the highest value of phosphor content (0.60 %) was observed from the application (50 kg ha^{-1}) of triple super phosphate fertilizer. This could be due to obtain the best nutrient balance in plants due to the application of phosphor fertilizer. Unlike the above effect, cultivars were found a non-significant effect on phosphorus content at both locations. The interaction treatments were significantly influenced on phosphor content. The highest value (0.81%) was produced from using Triple Super Phosphate x Brazowe and the lowest value (0.23 %) obtained from the Agriculture Sulfur x Libra at the first location. For the second location, the highest value attained from the interaction Triple Super Phosphate x Libra which was (0.84 %). These results in the same line with the results (10) they found that the highest value of phosphorus content (2.47 mg g^{-1}) obtained from the interaction between (75 kg ha^{-1} of triple super phosphate x 44NK of soybean cultivar).

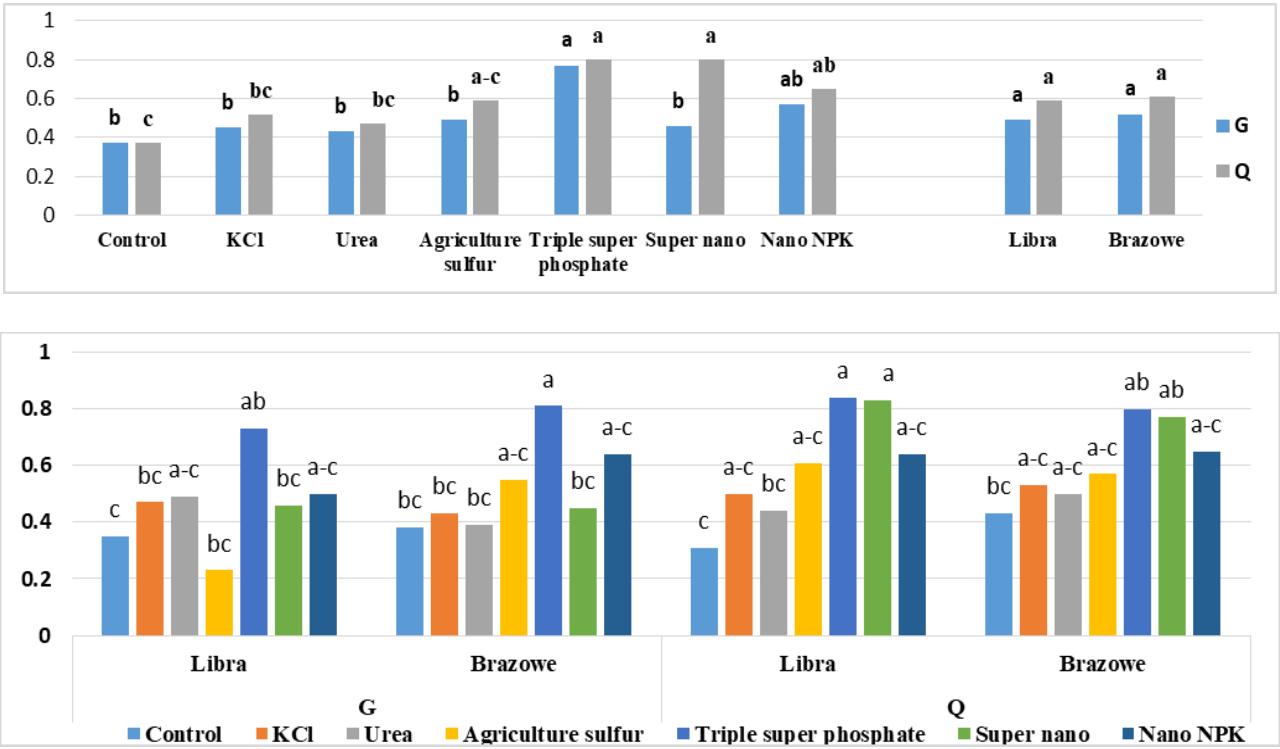


Figure 1. Phosphorus content % as affected by fertilization treatments, cultivars, and their interactions at G= Grda-rasha and Q= Grdmala, A = cultivars and type of fertilizers, B= two-factor interactions

d- Potassium content %

The data in Fig. 2 shows that the type of fertilizers application had a significant effect on potassium percentage. The highest mean value 0.53 and 0.46 % was obtained in first followed by second location, from Nano NPK fertilizer. These results support the conclusion that has been arrived by (2) they observed that foliar application of 75% Nano NPK-fertilizer + 25% mineral produced a significantly higher mean value of wheat K content which is (1.8%). This results agreement with the results reported by (32) that K% is affected by foliar application on Nano fertilizers. The highest value for potassium were (0.74, 0.83 and 0.79) % which were recorded from foliar application of Super-Nano at both locations and their averages respectively. The differences between cultivars caused a significant effect on potassium % at ($P \geq 0.05$) at Grdmala. The Libra cultivar was in the first rank and followed by Brazowe. The highest mean value was 0.46 and 0.35 % found in both locations respectively, for the Libra cultivar. This result supports the previous findings of (18). The interaction between treatments positively affected this nutrients

concentration (Fig. 2). the highest value 0.61 and 0.49 % found from the interaction between Nano NPK x Libra, and the lowest values 0.19 and 0.16 % was revealed from Control x Libra and Control x Brazowe respectively, for both locations. (21) demonstrated that Nano-NPK is considered the biological pump for plants to absorb nutrients and water. Therefore, water influence after adding Nano- materials was increased, and the plants absorbed N, P, and K along with the absorbed water. Thus, the production was also increased, as reported by (19).

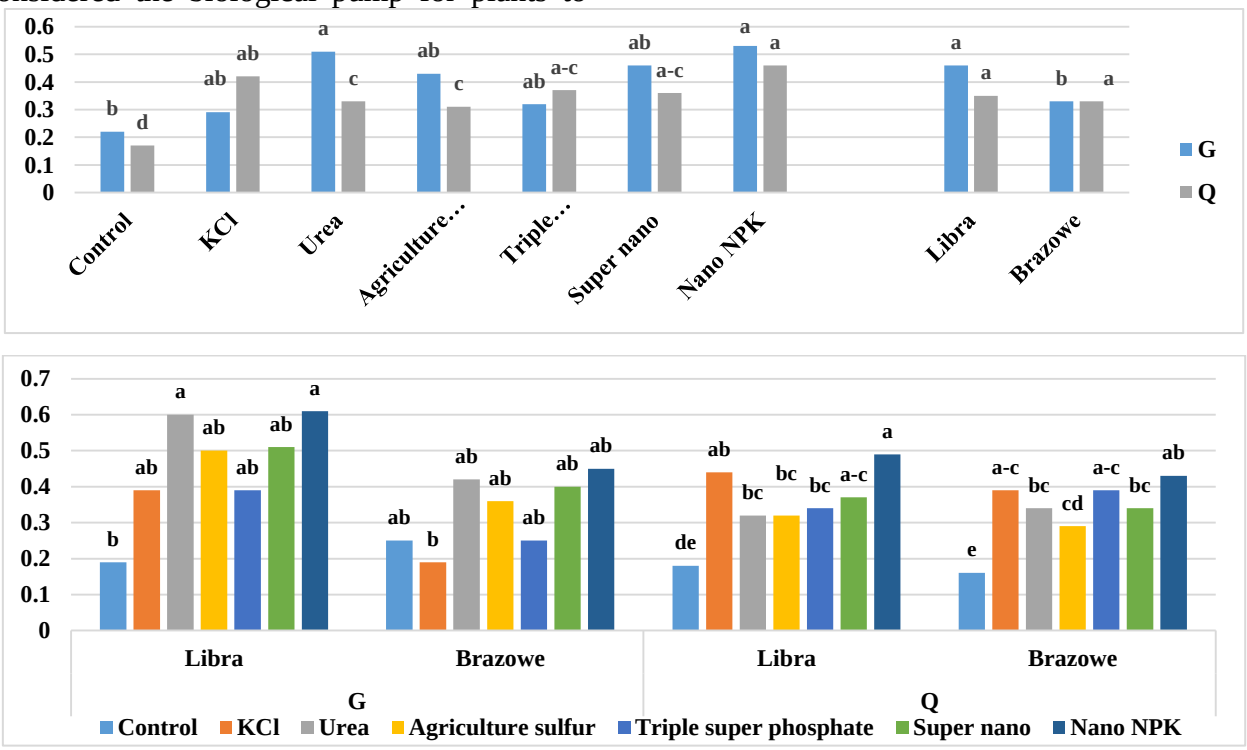


Figure 2. Potassium content % as affected by fertilization treatments, cultivars and their interactions at G= Grda-rasha and Q= Grdmala, A= cultivars and type of fertilizers, B= two-factor interactions

2. Effect of fertilizer treatments, cultivars, and their interactions on active substance

a. **Mucilage concentration %**

The mucilage content of flaxseed was affected significantly by the application of fertilizers. Table (4) shows that the maximum mean concentration of mucilage of seed (30.70 %) was attained from the soil application of urea fertilizer and the lowest value (24.32 %) was from control treatment at the Grda-rasha location. Conversely, at the Grdmala the highest mean value (39.26 %) was obtained from the foliar application of (Nano NPK) as compared to the lowest value (26.27 %) from the control.

Table 4. Effect of fertilizer treatments, cultivars, and their interactions on mucilage content %

Fertilizer treatments	Locations					
	Grda-rasha -L1			Grdmala-L2		
	Libra	Brazowe	Mean of Fertilizers	Libra	Brazowe	Mean of Fertilizers
Control	24.59 ^{cd}	24.06 ^{d}	24.32 ^{c}	26.03 ^{c}	26.51^{c}	26.27 ^{c}
KCl	30.98 $^{a-d}$	29.34 $^{a-d}$	30.16 ^{a}	28.19 ^{bc}	37.83 ^{a}	33.01^{b}
Urea	35.81 ^{a}	25.59 ^{bcd}	30.70 ^{a}	36.36 ^{ab}	32.29 ^{ab}	34.33 ^{ab}
Agriculture Sulfur	29.33 $^{a-d}$	26.24 ^{bcd}	27.79 ^{ab}	26.36 ^{c}	37.29 ^{bcd}	31.83 ^{b}
Triple Super Phosphate	27.24 ^{bcd}	32.04 ^{abc}	29.64 ^{a}	31.77 ^{abc}	34.17 ^{abc}	32.97 ^{b}
Super Nano-fertilizer	25.39 ^{bcd}	32.97 ^{ab}	29.18 ^{a}	34.84 ^{abc}	34.33 ^{abc}	34.58 ^{ab}
Nano NPK	29.51 $^{a-d}$	25.22 ^{cd}	27.36 ^{ab}	40.48 ^{a}	38.02^{a}	39.26 ^{a}
Mean of cultivars	28.98 ^{a}	27.92 ^{a}		32.00 ^{a}	34.35^{a}	

The cultivars did not significantly effect on mucilage content of flaxseed at ($P \geq 0.05$), but there are differences between mucilage % from both locations. Grdmala surpasses Grda-rasha by (10.42 and 23.03 %) for both Libra and Brazowe cultivars. Interaction between the studied treatments on the mucilage content. The highest value (35.81 %) was obtained from the interaction treatment Urea x Libra. In comparison, the lowest value (24.06 %) was produced from Control x Brazowe at the Grda-rasha location. Whereas at Grdmala, the interaction treatments of Nano NPK x Libra obtained the maximum value (40.48 %) and minimum value (26.03 %) was produced from interaction treatment of Control x Libra.

b. Total phenol content (mg 100 g^{-1})

Table (5) shows the total phenol content of flax was significantly affected by fertilizers application. The highest mean values (9.94 and 12.49 mg 100 g^{-1}) were obtained from the application of urea fertilizer at both locations, comparing with control treatment which produced (7.65 and 6.83 mg 100 g^{-1}) respectively, it could be due to the effect of nitrogen in the formation of each of the compounds erythrose -4- phosphate in the process of photosynthesis and (phosphoenol pyruvate) in the pathway of glycolysis, and this is reflected in the stimulation of the pathway (shikimic acid) that produces the two amino acids , phenylaninoterosene , both of which are included in the construction of the phenolic compounds in the enzymes (23). The results, in agreement with (20). The cultivars affected significantly on total phenol content at Grda -rasha location only. The maximum and minimum mean value 9.17 and 8.26 mg 100 g^{-1} was achieved from the Libra cultivar and Brazowe cultivar respectively. The difference did not significant at the Grdmala location. This agrees with the results (32) who observed differences between cultivars in these traits. There are also significant interactions between fertilizers and cultivars for phenol content, the greatest value (11.59 mg 100 g^{-1}) obtained from interaction treatment of Urea x Libra. In comparison, the lowest value (7.30 mg 100 g^{-1}) was produced from interaction treatment of (Control x Libra) at Grda-rasha location. On the other hand, at Grdmala, the highest value 13.72 mg 100 g^{-1} was obtained from interaction treatment of Urea x Brazowe, while the lowest value 6.54 mg 100 g^{-1} was obtained from interaction treatment of Control x Brazowe compared with the other oil bearing plants, soybean, olive, and sesame, the total phenolic content of 82 flaxseeds was found to be lower than olive but greater than soybean and sesame (27).

Table 5. Effect of fertilizer treatments, cultivars, and their interactions on total phenol content (mg 100 g^{-1})

Fertilizer treatments	Locations					
	Grda-rasha-L1			Grdmala-L2		
	Libra	Brazowe	Mean of Fertilizers	Libra	Brazowe	Mean of Fertilizers
Control	7.30 ^{e}	7.99 ^{cde}	7.65 ^{c}	7.11 ^{de}	6.54 ^{e}	6.83 ^{c}
KCl	7.92 ^{de}	8.58 $^{b-e}$	8.25 ^{bc}	9.66 $^{b-e}$	11.30 ^{abc}	10.48 ^{b}
Urea	11.59 ^{a}	8.28 $^{b-e}$	9.94 ^{a}	11.25 ^{abc}	13.72 ^{a}	12.49 ^{a}
Agriculture Sulfur	7.93 ^{de}	7.83 ^{de}	7.89 ^{bc}	11.51 ^{abc}	12.18 ^{ab}	11.85 ^{ab}
Triple Super Phosphate	10.1 ^{abc}	8.17 $^{b-e}$	9.14 ^{ab}	11. 04 ^{abc}	10.71 $^{a-d}$	10.88 ^{ab}
Super Nano-fertilizer	9.09 $^{b-e}$	7.38 ^{e}	8.24 ^{bc}	11.96 ^{abc}	8.91 ^{cde}	10.43 ^{b}
Nano NPK	10.24 ^{ab}	9.60 $^{a-d}$	9.92 ^{a}	10.37 $^{a-d}$	10.15 $^{a-e}$	10.26 ^{b}
Mean of cultivars	9.17 ^{a}	8.26 ^{b}		10.42 ^{a}	10.50 ^{a}	

c. Antioxidant activity %

Data in Table (6) shows the application of fertilizers affected significantly on antioxidant activity. The highest and lowest means value 75.30 and 65.67 % were produced from super Nano fertilizer and control treatment at Grda-rasha. This confirms with result of (20) who mentioned increasing in antioxidant by applying nitrogen fertilizer. For Grdmala field, the highest value (86.53 %) was obtained from triple super phosphate, while the lowest value reported from control treatment (80.07 %). Furthermore, the cultivars were significantly affected on antioxidant activity. The highest mean value was produced for the Libra which was (71.71 %) and the lowest value (68.70 %) was produced for Brazowe at Grda-rasha. On the contrary, in the Grdmala field, the highest

value (84.79 %) record for the Brazowe and the lowest value (82.08 %) for the Libra, these results in harmony with (18). According to the locations, the two cultivars have different behavior, as there are significant differences between the two locations in antioxidant activity as presented (70.20 and 83.24%). In addition, there were significant interactions between type of fertilizers application and flaxseed cultivars for antioxidant activity (Table, 6). From the application of (Super Nano fertilizer x Libra), the highest value (81.26 %) was produced. In the second location, the interaction of Triple Super Phosphate x Brazowe attained the highest value (88.92 %), the lowest value was obtained from the control x Libra for the two locations.

Table 6. Effect of fertilizer treatments, cultivars, and their interactions on antioxidant activity %.

Fertilizer treatments	Locations					
	Grda-rasha-L1			Grdmala-L2		
	Libra	Brazowe	Mean of Fertilizers	Libra	Brazowe	Mean of Fertilizers
Control	65.47^{b}	65.86^{b}	65.67^{b}	78.99^{c}	81.14^{bc}	80.07^{b}
KCl	70.09^{b}	69.97^{b}	70.03^{ab}	81.83^{bc}	87.84^{ab}	84.84^{ab}
Urea	67.66^{b}	68.10^{b}	67.88^{b}	81.10^{bc}	85.57^{abc}	83.34^{ab}
Agriculture Sulfur	74.77^{ab}	69.96^{b}	72.37^{ab}	83.01^{abc}	85.41^{abc}	84.21^{ab}
Triple Super Phosphate	72.89^{ab}	66.28b	69.59^{ab}	84.15^{abc}	88.92^{a}	86.53^{a}
Super Nano-fertilizer	81.26^{a}	69.34^{b}	75.30^{a}	81.55^{bc}	81.02^{c}	81.29^{b}
Nano NPK	69.81^{b}	71.35^{b}	70.58^{ab}	83.90^{abc}	80.98^{c}	82.44^{ab}
Mean of cultivars	71.71^{a}	68.70^{b}		82.08^{b}	84.79^{a}	

3. Effect of fertilizer treatments, cultivars, and their interactions on Fatty acids% composition

a. Oleic acid content %

The data presented in Figure (3), revealed that fertilizer application significantly affected oleic acid content. The highest mean value for omega-9 (20.35%) was obtained from agriculture sulfur treatment at Grda-rasha location. On the other hand, at Grdmala, by application of triple super phosphate obtained the highest mean value was (19.45%) Additionally, the same figure indicates to a positive influence of different cultivars on the oleic acid content. The first cultivar, Libra shows the highest mean value (17.53 %), followed by the second Brazowe (16.99 %), at Grda-rasha field. While, these results conversely with Grdmala field, the highest mean of oleic (16.29 %) was obtained from Brazowe cultivar, and Libra cultivar produced the lowest value (15.76 %). This result indicates that Brazowe is better than Libra, which could be due to the genetic behavior of the cultivars and its adaptation to the local climatic conditions. The interactions between the two factors were also found to be significant on the oleic content. The highest (22.40 %) and lowest (15.10 %) value of oleic acid content were produced from the treatment combination (Agriculture Sulfur x Brazowe) and (KCl x Brazowe), respectively at Grda-rasha location. Furthermore, the results indicated that the omega-9 was affected significantly by each of the interactions: (Triple Super Phosphate x Libra) and (Control x Libra) offered the highest and lowest value (22.95 versus 14.03%) at the Grdmala location respectively.

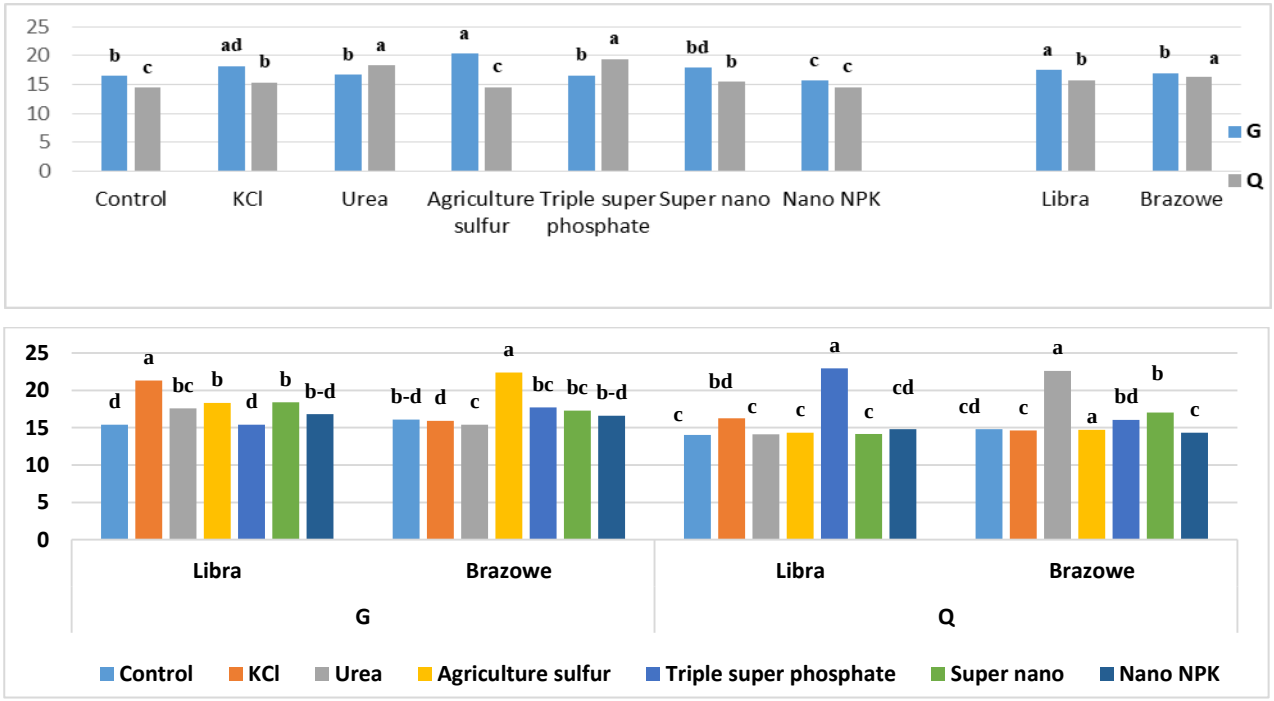


Figure 3. Oleic acid content % as affected by fertilization treatments, cultivars, and their interactions at G= Grda-rasha and Q= Grdmala, A = cultivars and type of fertilizers, B= two-factor interactions

a- Linoleic acid %

The presented results in Figure (4), indicated to a significant effect of fertilizers on Linoleic content. The maximum percentage of omega-6 (29.40 %) was obtained from soil application of urea. In comparison, the minimum content of linoleic (27.75 %) was noted from agriculture sulfur) or (Super Nano) treatments at the Grda-rasha. At Grdmala field the highest and lowest mean values (25.40 and 23.60 %) were produced from the application of super Nano and urea fertilizer respectively. Contrary to the above results, data analysis revealed non-significant differences occurred on linoleic due to differences in flaxseed cultivars.

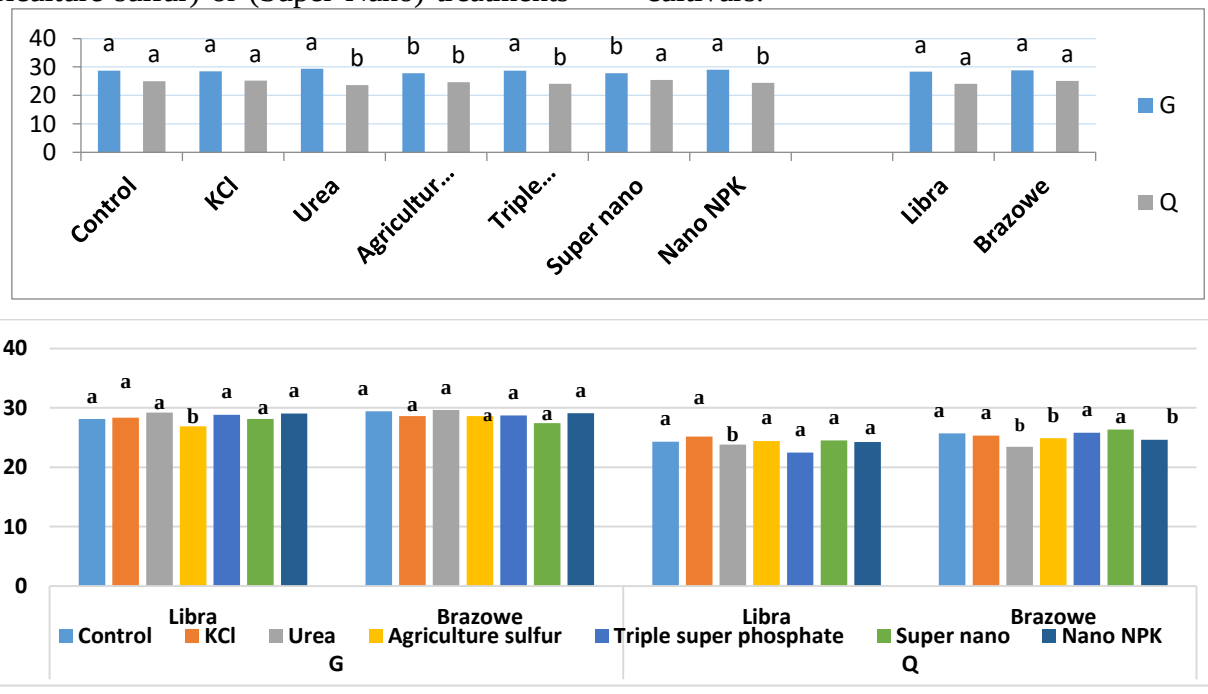


Figure 4. Linoleic acid content % as affected by fertilization treatments, cultivars, and their interactions at G= Grda-rasha and Q= Grdmala, A = cultivars and type of fertilizers, B= two-factor interactions

A substantial difference was found among the interaction between fertilizer and cultivars. The highest linoleic content (29.63 %) was obtained from Urea x Brazowe. In contrast, the lowest percentage (26.90 %) was noted from Agriculture Sulfur x Libra at Grda-rasha location. (6) reported that increases in mineral fertilization up to 80 kg N ha^{-1} in form of urea significantly increased the content of linoleic in seeds of two flax cultivars. From the interaction between Super Nano x Brazowe attained the maximum content of omega-6 in the flaxseed cultivar (26.32 %), while the lowest value (22.44 %) was obtained from Triple Super Phosphate x Libra at Grdmala location.

a- Linolenic acid content %: Data Figure (5) shows Nano NPK fertilizer shows the highest mean value of omega-3 (39.10 %), and the lowest value (36.65 %) was produced for agricultural sulfur from first location. This result following (33) who indicated that from the application of (50 kg Sulphur ha^{-1} + 10 kg Boron ha^{-1}) obtained the highest value of linolenic. At Grdmala, the highest and lowest mean values (37.35 and 33.80 %) were obtained from Nano NPK and triple super phosphate fertilizers, respectively. This result disagrees with the results of (34) found that the highest value of linolenic acid (48.15 %) was obtained by applying 70 kg P_2O_5 ha^{-1}. Like most of the quality contributing traits, the linolenic acids content was not affected significantly by cultivars for both locations.

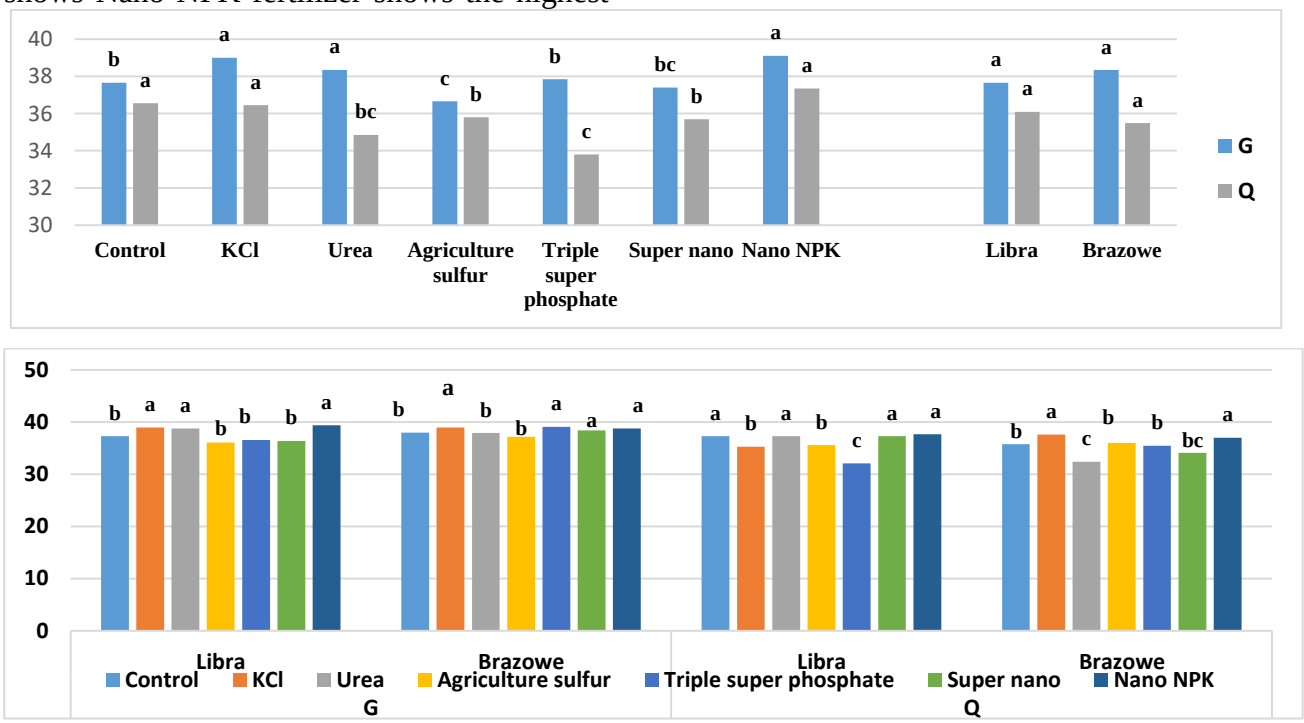


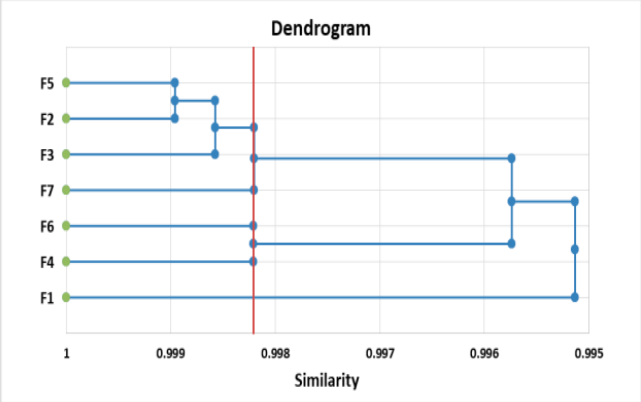
Figure 5. Linolenic acid content % as affected by fertilization treatments, cultivars, and their interactions at G= Grda-rasha and Q= Grdmala, A = cultivars and type of B= two-factor interactions

The interaction (Nano-NPK x Libra) in (Fig. 7) shows maximum omega-3 (39.40 %). In contrast, the lowest value (36.10 %) was attained from (Agriculture Sulfur x Libra) at the first location. These results disagree with the results (24) they illustrated that increase in the concentration of sulfur from 100 - 400 mg L^{-1} causes a significant increase in flax quality. At the Grdmala field, the highest and lowest linolenic acids x content (37.70 and 32.1 %) was obtained from Nano NPK x Libra and Triple Super Phosphate Libra.

Cluster analysis

The statistical analysis was conducted using XLSTAT, 2016. To identify the most important fertilizers and their grouping for focusing on their effect on the chemical composition of flax using the Agglomerative hierarchical clustering (AHC). Depending on cluster analysis the studied fertilizer types were classified into four clusters using similar

methods. The clusters were C1, C2, C3, and C4 representing fertilizer types groups depending on their similarity. The first cluster included F_1 (Control), the second cluster included F_2 (KCl), F_3 (urea), and F_5 (TSP), cluster 3 included F_4 (Agriculture Sulfur) and F_6 (Super Nano) finally cluster four had only F_7 (Nano NPK) as shown in (Figure 6). Relying on cluster analysis for the studied fertilizer types as shows in Fig. 7 the fertilizer types classified into three clusters depending on similarity which were C_1, C_2, and C_3. The first cluster included F_1 (Control), the second cluster included most the fertilizers (F_2 to F_6) while the third cluster included F_7 only. The vertical line is responsible for limiting the similarity between groups or dividing the studied characteristic.



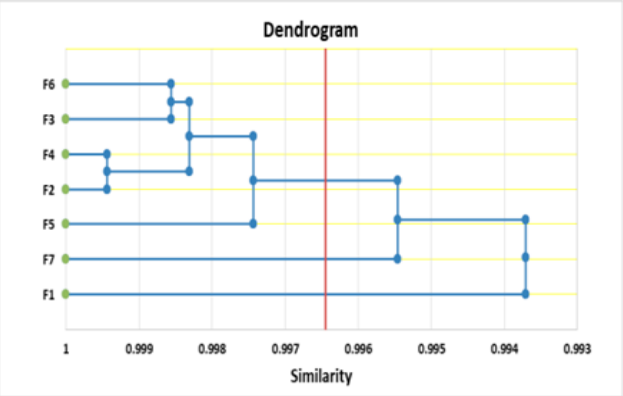


Figure (6 and 7). The dendrogram was sketched from cluster analysis of the studied fertilizers of the (13) chemical traits studied in flax crops for both locations

Conclusion

The most outstanding conclusions that can be drawn from this study are:

The application of different types of fertilizer caused a significant increase in most important studied characteristics. Additionally, increased the concentration of some natural products such as mucilage and total phenol, the best fertilizer treatments were Nano NPK, Super Nano, and triple super phosphate, and some of the medical properties such as antioxidant activity and ploy-unsaturated fatty acids increased with triple super phosphate and Nano NPK. The cultivars also significantly affected on: total phenol, oil %, and some chemical products. The interaction treatments indicated positive effects on some natural products creating different growth conditions for the plant. Most of the studied characteristics were reach the highest value at the Grdmala location compared to Grda-rasha due to different climatic conditions and soil fertility of studied locations. The Principal Component Analysis (PCA) and Agglomerative Hierarchical Clustering (AHC) were grouped into four classes at Grda-rasha and three classes at Grdmala according to fertilizer types.

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