Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – Agriculture College)

RESPONSE OF TWO FLAX CULTIVARS TO CHEMICAL AND NANO-FERTILIZERS AND THEIR INFLUENCE ON GROWTH AND YIELD PARAMETERS

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Article info

Received: 2021-07-18
Accepted: 2021-10-07
Published: 2021-12-31

DOI -Crossref:
10.32649/ajas.2021.176003

Cite as:
Omer, B. A., and B. J. Mahmood. (2021). Response of two flax cultivars to chemical and nano-fertilizers and their influence on growth and yield parameters. Anbar Journal of Agricultural Sciences, 19(2): 285-305.

Abstract

This study was done during (11th of November to 8th of June ,2020) at two locations (Grdarasha and Grdmala) in Erbil governorate to test the influence of seven fertilizer treatments [Control, Nano-NPK, Super Nano, Triple super phosphate, Urea, KCl and agricultural sulphate], two flax cultivars (Libra and Brazowe) and their interactions on growth, yield and oil content. The results indicated to significant effect of the studied factors and their interactions on growth, yield and oil % of the two flax seeds. The maximum seed yield 4.65 and 6.27 g plant-1 was recorded from plots sprayed with Nano-NPK, while the lowest values 2.58 and 4.45 g plant-1 was recorded from control in both locations respectively. While the highest seed yield value 4.42 and 5.86 g plant-1 were obtained from Brazowe cultivar. On the other hand, the interaction treatment of (Super Nano* Brazowe cultivar) and (TSP * Brazowe) were recorded the highest seed yield per plant which were 5.97 and 6.99 g plant-1 respectively. The highest oil values 32.96, 30.73 and 33.42% was observed from treatments Nano-NPK, Brazowe cultivar and treatment combination of (Nano-NPK* Brazowe cultivar) respectively.

Keywords: Nano fertilizer, Flax cultivars, oil percentage, Yield and yield components.

استجابة صنفين من الكتان للأسمدة النانوية والكيمياوية وتأثيرهما في النمو والحاصل

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الخلاصة

اجريت هذه الدراسة في موقعي (كرد ر شه وكرد ملا) ضمن محافظة اربيل خلال الفترة من 11 / 11 الى 8 /6 لدراسة تأثير سبعة انواع من الاسمدة (معاملة المقارنة والنانوي المركب والسوبر نانو وسوبر فوسفات الثلاثي واليوريا وكلوريد البوتاسيوم والكبريت الزراعي) وصنفين من الكتان (ليبرا وبرازوا) والتداخل بينهما على صفات النمو والحاصل ومحتوى الزيت. دلت النتائج على تأثيرات معنوية للعوامل المدروسة والتداخل بينهما في حاصل البذور ونسبة الزيت حيث سجلت اعلى حاصل للبذور 4.65 و6.27 غم/ نبات في معاملة الرش بالسماد النانوي المركب في حين لوحظت أدني حاصل 2.58 و4.45 غم / نبات في معاملة المقارنة ولكلا الموقعين على التوالي، سجلت صنف برازوا اعلى حاصل 4.22 و6.86 غم/ نبات لكلا الموقعين على التوالي. كما سجلت اعلى حاصل 5.97 و6.99 غم/ نبات في المعاملة العاملية (برازوا *والسماد النانوي المركب) ولكلا الموقعين على التوالي. اما بخصوص نسبة الزيت في موقع كرد ملا فقد سجلت اعلى القيم 32.96 و30.73 و33.42% في المعاملات السماد النانوي والصنف برازواو التداخل بينهما على التوالي.

كلمات مفتاحية: السماد النانوي، أصناف الكتان، نسبة الزيت، مكونات المحصول والحاصل.

Introduction

Flax (*Linum usitatissimum* L.) is an essential crop as it is known as the producer of two substances: linen products from fiber and edible oil from flaxseed which contain 30 – 48% of oil abundant in unsaturated fatty acids, chemical industry in drying oil (for the production of printing and other inks, varnishes, paints, and linoleum (32). Since most of the agricultural soils in north Iraq are calcareous, due to high calcium carbonate content 8.9-31.38 % which caused low availability of essential nutrients for plants due to fixation 80-90% of applied phosphorus fertilizer to calcareous soil of northern Iraq (7).

(13) Indicated to volatilization of 50% of applied urea to calcareous soil in Erbil. (33) studied the Fe status for 20 agricultural lands in Sulaimani governorate, the results indicated to low available iron in the studied area that ranged between 1.66 to 2.98 mg Fe kg soil^{-1}, which was less than the critical value of (4 mg Fe kg^{-1} soil) this may be

due to high calcium carbonate content that ranged from 31.70 to 32.53%. (29) Refereed to negative nutrient balance index or imbalance among N, P, K, Mg and Fe for plants grown in some calcareous soils in Erbil governorate due to high calcium carbonate content of the studied. (25) studied the phosphorus availability for the main soil orders in Iraqi Kurdistan Region (Mollisols, Vertisols, and Aridisols) the results indicated to low availability of phosphorus, nitrogen and potassium in the studied soils. The above studies explain the low availability of some essential nutrients in calcareous soil, for this reason the fertilization regards as one of necessary agricultural practices for increasing yield and quality.

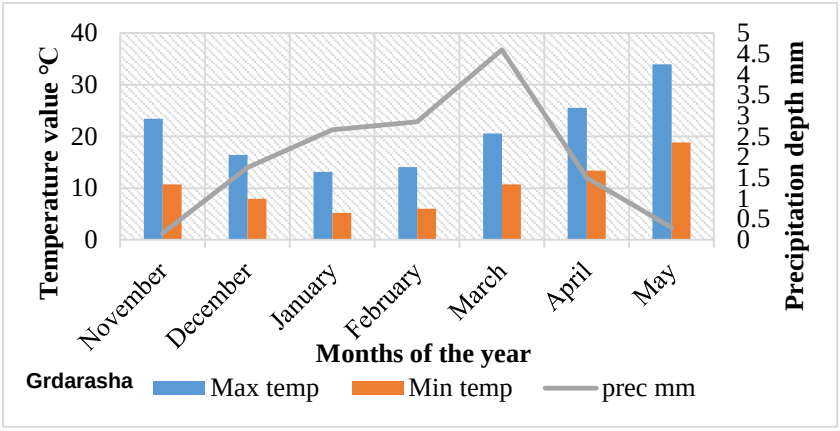
It is necessary to increase flax productivity per unit area which could be achieved by using high yielding cultivars and improving the agricultural treatments (9). The yield of linseed can be increased by more than 100% over the prevailing management practices under rained condition with proper fertilization, weed control and plant protection measures (30). On the other hand, the flax cultivars had great influence on yield and quality of flax (3 and 17). (21) Showed that foliar application of phosphorous to flax caused significant increase in flax yield. The hypothesis of this research is the Nano fertilizers are better than traditional fertilizer in their effects on growth, yield and oil content of flax cultivars. Nano fertilizer are smart fertilizer and don't convert to unavailable form in the soil, therefore they could cause increase in flax growth and yield.

Nano fertilizers (NFs) is the modern fertilizer or alternative technologies that is more efficient, eco friending, not toxic and more efficient that have high potential to increase yield and quality of plants due to its role in increasing in efficacy of nutrient uses. Nano fertilizers have high activity due to their high surface 28 and 27. It recorded the significant role in agriculture field such as germination percentage, growth, increasing the nutrients availability, Chlorophyll formation and production of dry matter. They can easily penetrate soil and roots, which consequently improve plant growth (14). Since there are little or no studies in Iraq and Iraqi Kurdistan region about the comparison between the influence of chemical and Nano fertilizers on growth and yield of flax cultivars, for above reasons the objective of this investigation is to comparison between two Nano fertilizers and four traditional chemical fertilizers in their influence on growth, yield and oil content of two flax cultivars at two different locations in Erbil governorate.

Material and Methods

Two field experiments were carried out in the winter seasons of 2019-2020 at the experimental farm of Agricultural Engineering Science with GPS reading of (Latitude 36˚4 N and Longitude 44˚2 E with Altitude of 415 meter above sea level, the second experiment was carried out at Grdmala site with GPS reading of (latitude 360 06.9 N, longitude 44 030 E, Altitude 413.8 meter above sea level, to study the role of chemical and Nano fertilizers on growth , yield and oil content of two flax cultivars *(Linum usitatissimum L.*) at two locations in Erbil governorate.

The experiment had been done under rain fed condition and irrigated according to crop requirement to avoid drought stress of the crop. Figure, 1 and 2 shows the depth of rainfall and temperature, for Grdarasha and Grdmala locations during the growing season of 2019-2020.



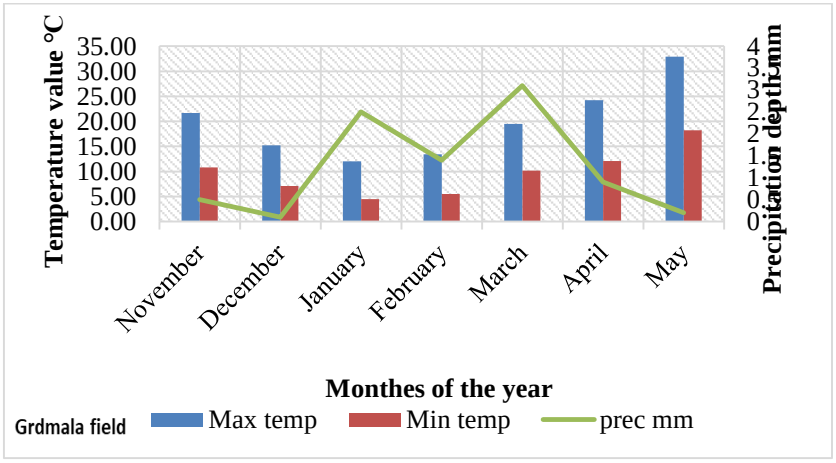


Figure 1 Metrological data recorded at the two experimental sites during (2019 2020).

The soils for both locations are calcareous with low organic matter content. The soils for both locations were silty clay loam and silty clay respectively. The soil for the second location is more fertile the soil of the first location due to higher concentration of N, P and K and lower calcium carbonate in the soil of the second location Table 1.

Table 1 some physical and chemical properties of studied field before plantin.

Soil properties		Units	Grda rasha	Grd mala
Particle distribution Size	**Sand**	(g kg^{-1})	127.54	118
	Silt		503.00	432
	Clay		369.46	450
Soil texture			Silty clay loam	Silty clay
Soil pH			7.65	7.86
ECe		ds m^{-1}	0.56	0.50
Organic matter content		(g kg^{-1} soil)	11.77	9.76
Calcium carbonate			312.00	250
Available nitrogen		(mg kg^{-1}soil)	23.5	38.80
Available Phosphorous		(µg g^{-1} soil)	3.42	9.3
Soluble ions		Ca^{2+}	1.99	2.50
		Mg^{2+}	1.88	1.55
		Na^{+}	0.72	0.95
		K^{+} $mmol_c^{-1}$	0.09	1.14
		HCO_3^-	3.22	3.50
		CO_3^{2-}	0	0
		Cl^-	1.07	2.3

The factorial experiment based on randomized completely block design (RCBD) with three replicates was used, the first factor comprised of seven fertilizer treatments which includes:

F_1 = Control, or spraying only distillated water.

F_2 = Application of 160 kg KCl ha^{-1} which equivalent to 32 g per experimental unit, which applied at sowing time.

F_3 = Application of 160 kg ha^{-1} urea which equivalent to 32 g per experimental unit that applied in two doses, the first dose (16 g) was added at sowing time (11^{th} November, 2019), while, the second dose (16 g) was applied at 5^{th} March, 2020.

F_4 = Foliar application of 200 mg L^{-1} agriculture sulfur to each experimental unit.

F_5 = Application of 160 kg ha^{-1} Triple super phosphate at sowing time which equivalent to 32 g per experimental unit.

F_6 = Foliar application of 200 mg L^{-1} Nano NPK 20, 20, 20.

F_7 = Foliar application of 200 mg L^{-1} Super Nano-fertilizer 200, that contains 6 ,3, 17, 4, 4, 2, 0.50, 0.50, 0.10, 1, 3 and 6% of N, P, K, Fe, Zn, Mn, Cu, B, Mo, Ca, Mg and S respectively.

The second factor was two flax cultivars: Libra was Poland cultivar imported from Agricultural Research Center-Erbil and Brazowe was imported from Agriculture Research Center- Baghdad.

The number of interaction treatments for each location = 7*2 = 14 interaction treatments.

Number of blocks or replicates =3

The number of experimental unit (plots) for each location = 14*3 = 42

Total number of plots or experimental unis =42 *2 =84

This implies that each experimental unit was represented by the combination of the two factors.

The land was divided into three blocks, each block consisted of 14 experimental units, the dimensions of each unit were (1m×1.5m), and each unit contained five rows, with

row spacing of 20 cm. On 11th November, the seeds were sown manually at the rate of 100 kg ha^{-1} which equivalent to 32 g per experimental unit on a silty clay soil. The irrigation and manually weed control were done whenever needed.

Studied characters included the following: Some morphological parameters: Representative samples of 20 plants were taken from the inner rows for each experimental unit during physiological maturity stages. The samples were used to study the following characters:

a. Plant height (cm) b. No. of primary branches c. No. of secondary branches. d. No. of pod $plant^{-1}$ e. Pod weight $plant^{-1}$ (g) f. No. of seeds pod^{-1} (From the selected plants in each experimental unit 50 pods were taken randomly shattered by hand, then mean number of seeds per pod were calculated. g. Weight of 1000 seeds (g).

Flax Yield:

a. Biological yield (g plant $^{-1}$)

The selected 20 plants were weighted, and then biological yield for each plant was calculated.

b. Seed yield (g plant $^{-1}$)

The seeds for the selected 20 plants of each experimental unit were threshed, sieved and impurities were removed and weighed, then calculate the mean per plant.

c. Harvest index was calculated as mentioned by (23) as follow:

$$HI = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Flax quality traits: Oil percentage was determined using Soxhlet apparatus for oil extraction as mentioned by Association of Official Analytical Chemists (1).

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 (26), the difference among means of treatments were tested using Duncan's multiple range test at level of significant 5% (15).

Results and Discussion

Effect of type of fertilizers, cultivars and their interactions on some morphological parameters: Plant height (cm): According to the data presented in table 2 the fertilizer types affected significantly on plant height in both locations, the highest average value was obtained from application of urea and TSP fertilizer 83.75 and 91.15 cm compared to control 79.01 and 80.58cm at Grdarasha and Grdmala respectively. Similar result reported by (4). Additionally, Table 2 indicates that there was a positive influence of different cultivar on plant height of flax. The maximum mean value of plant height was recorded for Libra (V_1) cultivar 86.01 and 88.01 cm and minimum value for Brazowe (V_2) cultivar 76.14 and 85.26 cm in both locations respectively. The V_1 cultivar surpassed the V_2, resulting in 12.62 and 3.22% increase in plant height at both locations respectively, this may be due to the genetic behavior of the cultivar and its adaptation to the local climatic conditions. The results are in

conformity to the findings of (5) who observed a significant effect of flax varieties on plant height.

The statistical analysis of the data revealed that the interaction between cultivars and fertilizers caused significant increase in plant height, the highest values 88.89 and 92.90 cm were recorded from interaction treatments of (Libra cultivar * Agriculture sulfur fertilizer) and (Libra cultivar *TSP fertilizer) for both locations respectively. On the other hand, the lowest values 73.93 and 75.45 cm were noted from interaction treatments treatment of (control * Brazowe) at both locations respectively. These results agree with those recorded by (31). The results concluded that the plant height at Grdmala location superior plant height at Grdarash location, this may be due to higher rainfall figure 1 and more fertile soil at the Grdmala location in comparing with Grdarasha soil due to low calcium carbonate, high available, P and K of Grdmala soil which were caused increase in nutrient availability then plant growth.

Table 2 Effect of type of fertilizers, flax cultivars and their interactions on plant height (cm) at the two locations.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	84.08 ^{ab}	73.93 ^{d}	79.01 ^{b}	
	KCI	84.40 ^{ab}	74.39 ^{d}	79.40 ^{b}	SE
	Urea	86.50 ^{a}	81.00 ^{bc}	83.75 ^{a}	(F) =1 .09
	Agriculture sulfur	88.89 ^{a}	75.15 ^{d}	82.02 ^{ab}	
	Triple super phosphate	86.32 ^{a}	75.33 ^{d}	80.83^{ab}	
	Super Nano-fertilizer	86.78 ^{a}	78.05 ^{cd}	82.41 ^{ab}	SE(F*C)
	Nano NPK	85.08 ^{ab}	75.10 ^{d}	80.09 ^{b}	= 1.55
	Mean of cultivars	86.01 ^{a}	76.14 ^{b}	SE(C) = 0.58	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	85.70 $^{b-e}$	75.45 ^{f}	80.58 ^{c}	
	KCI	88.40 $^{a-d}$	92.48 ^{ab}	90.44 ^{a}	
	Urea	91.550^{abc}	86.73 $^{a-e}$	89.14 ^{ab}	
	Agriculture sulfur	89.93 $^{a-d}$	87.45 $^{a-d}$	88.69 ^{ab}	SE (F)=1.50
	Triple super phosphate	92.90 ^{a}	89.40 $^{a-d}$	91.15 ^{a}	
	Super Nano-fertilizer	84.58 ^{cde}	85.05 ^{cde}	84.82^{bc}	
	Nano NPK	83.03 ^{de}	80.28 ^{ef}	81.65 ^{c}	SE (F*C)
	Mean of cultivars	88.01 ^{a}	85.26 ^{b}	SE(C)=0.80	= 2.12

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Primary branches: The primary branches per plant were significantly affected by the application of fertilizer types 3. The maximum mean value 2.77 and 3.61 branches plant^{-1} was obtained from application of Nano NPK fertilizer as compared with control which were 2.18 and 2.50 branches plant^{-1} for both locations respectively. This increase in number of branches per plant explains the response of flax plant to Nano-NPK which improved micro climate for plant growth in comparing with control treatment, which caused enhance in nutrient absorption then increase in vegetative growth and number of branches. These results agree with (26).

The cultivars were not affected significantly on number of branches per plant. Table 3 showed that the interaction between fertilizers and cultivars had significant influence

on primary branches per plant. The maximum value (3.33 branches plant^{-1}) was documented from interaction treatment of (Brazowe * Super Nano fertilizer) at Grdarasha compared to (Control x Libra) which was 1.93. At Grdmala the maximum value (3.65 branches plant^{-1}) was recorded from interaction treatment of (Libra * Nano NPK), whereas, the lowest value (2.30 branches plant^{-1}) was obtained from (Control * Brazowe). In this respect, (20) reported that flax cultivars were significantly responded to foliar application of macro-nutrients. The results can be summarized that in case of single facto the cultivars was not affected on number of primary branches per plant, while in case of interaction treatments the highest value was recorded from interaction treatment of (Brazowe * Super Nano fertilizer) at Grdarasha, while at Grdmala location the heights value (3.65 branches plant^{-1}) was recorded from interaction treatment of (Libra * Nano NPK). It explain the role of soil properties in response of plants applied fertilizers since the concentration of available phosphorus is very low in Grdarasha soil and calcium carbonate is very high for this reason Brazowe cultivar responded to Super Nano, while at Grdmala location Libra cultivar responded to Nano-NPK due higher available phosphorus and lower calcium carbonate content in comparing with Grdarasha location Table 1. Or it means the variation between soil environments of the studied two locations may create two different media for plant growth and also may cause differing in cultivars response to the applied fertilizers.

Table 3 Effect of type of fertilizers, cultivars and their interactions on no. of primary branch in the two locations.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	1.93 ^{e}	2.43 ^{bcd}	2.18 ^{b}	
	KCI	2.33 ^{cde}	2.55 ^{bcd}	2.44 ^{ab}	SE
	Urea	2.45 ^{bcd}	2.87 ^{b}	2.66^{a}	(F) = 0.10
	Agriculture sulfur	2.78 ^{bc}	2.60 ^{bcd}	2.69^{a}	
	Triple super phosphate	2.37 ^{cde}	2.75 ^{bc}	2.56^{a}	
	Super Nano-fertilizer	2.15 ^{de}	3.33 ^{a}	2.74 ^{a}	SE (F*C)
	Nano NPK	2.78 ^{bc}	2.77 ^{bc}	2.77 ^{a}	= 0.15
	Mean of cultivars	2.40^{a}	2.75^{a}	SE(C) = 0.06	
Grdmala field	**Fertilizers treatments**	**Libra**	**Brazowe**	**Mean of fertilizers**	
	Control	2.70 ^{e}	2.30 ^{f}	2.50 ^{c}	
	KCI	3.38 ^{abc}	3.38 ^{abc}	3.38 ^{ab}	
	Urea	3.0 8^{cde}	3.38 ^{abc}	3.23 ^{b}	SE
	Agriculture sulfur	3.28 $^{a-d}$	3.20 ^{bcd}	3.24 ^{b}	(F)=0.09
	Triple super phosphate	3.47 ^{abc}	2.87 ^{de}	3.17 ^{b}	
	Super Nano-fertilizer	3.17 ^{bcd}	3.10 ^{cde}	3.13 ^{b}	
	Nano NPK	3.65 ^{a}	3.58 ^{ab}	3.61 ^{a}	SE (F*C)
	Mean of cultivars	3.24 ^{a}	3.11 ^{a}	SE(C)= 0.05	=0.13

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Secondary branches plant^{-1}: Table 4 indicated to significant effect of fertilizers type on number of secondary branches per plant. The highest value 12.59 and 14.65 branches plant^{-1} was recorded from spraying Nano NPK fertilizer at both locations respectively. The studied two cultivars were responded in secondary branches plant^{-1} to the application of fertilizers, the maximum value 12.80 branches plant^{-1} was noted for Brazowe cultivar whilst, the lowest value 9.40 was for Libra cultivar in first location. In the same respect, at Grdmala location the highest and lowest value was 13.64 and 12.42 were recorded for Brazowe cultivar respectively. This result is in agreement with the result of (10) who illustrated that Amon cultivar produced the highest values of number of branches per plant as compared to other two cultivars Olin and Giza-8 cultivar. The differences between the tested cultivars mainly attributed to the differences in their genetically constitution and their response to the environmental conditions. Such results are in harmony with those obtained by (2 and 18).

The interaction among the fertilizer and cultivar had significant influence on the number of secondary branch per plants as shown in table 4. The results noted that the maximum number of secondary braches per plant was 14.18 which was recorded from the interaction treatment of (Brazowe * Nano NPK) and minimum value for control 6.93 for (Libra * Control) in Grdarasha. Conversely, in Grdmala highest secondary branches 16.28 was recorded from the interaction between (Brazowe * Nano NPK) as compare to interaction treatment of (Libra * Control). The results indicate to great effect of Nano-NPK on number of branches this may be play a great role in growth, yield and quality of flax.

Table 4 Effect of type of fertilizers, cultivars and their interactions on no. of secondary branches in the two locations (branches plant^{-1}).

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	6.93 ^{h}	12.33 ^{c}	9.63 ^{c}	
	KCI	9.38 ^{fg}	10.65 ^{de}	10.01 ^{c}	SE
	Urea	9.63 ^{ef}	13.13 ^{abc}	11.38 ^{b}	(C) = 0.24
	Agriculture sulfur	10.53 ^{de}	13.00 ^{bc}	11.76 ^{b}	
	Triple super phosphate	9.93 ^{def}	12.20 ^{c}	11.06 ^{b}	
	Super Nano-fertilizer	8.40 ^{g}	14.10 ^{ab}	11.25 ^{b}	SE (F*C)
	Nano NPK	11.00 ^{d}	14.18 ^{a}	12.59 ^{a}	= 0.34
	Mean of cultivars	9.40^{b}	12.80^{a}	SE (C) =0.13	
Grdmala field	**Fertilizers treatments**	**Libra**	**Brazowe**	**Mean of fertilizers**	
	Control	11.15 ^{c}	11.78 ^{c}	11.46 ^{c}	
	KCI	13.00 ^{bc}	12.98^{bc}	12.99 ^{bc}	
	Urea	11.33 ^{c}	13.33 ^{abc}	12.34 ^{bc}	SE

Agriculture sulfur	12.77 bc	15.70 ab	14.23ab	(C) = 0.62
Triple super phosphate	12.38 c	13.65 abc	13.01 bc	
Super Nano-fertilizer	12.67bc	11.73 c	12.20 c	
Nano NPK	13.65 abc	16.28 a	14.65 a	SE (F*C)
Mean of cultivars	12.42b	13.64a	SE (C) = 0.32	= 0.88

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Number of pod plant^{-1}: Table 5 clarified that super Nano and Nano NPK affected significantly on number of pods plant^{-1} in both locations. The highest and lowest values for both locations were 125.92 and 118.33 and 82.88 and 99.94 pods plant^{-1}. The results are indicated to the role of nutrients especially phosphorus in pod and seed formation, since the mentioned two Nano fertilizers are the sources for phosphorus for this reason they caused increase in pod formation. On the other hand, the plants are responding 100% to Nano-fertilizer in contrast their response to traditional fertilizers. Or this may be due to the role of Nano fertilizers in increasing number of secondary branches then then of pod table 4. These results are in agreement with those reported by (16).

Table 5 clarified that there are significant differences between the studied cultivars in the number of pod plant^{-1} the highest values (130.02 and 113.84 pod plant^{-1}) were recorded for Brazowe for both Grdarasha and Grdmala locations respectively, while Libra cultivar recorded the lowest values (90.25 and 108.25 pod plant^{-1}) for both locations respectively. This may be due to the differing in genetically properties of the studied cultivars in additional to phenotypic effects which caused the variation in number of secondary branches per plant in both locations table 4 then caused the differing in number of pods per plant. The interaction between fertilizer types and cultivars has significant effect on the studied traits, the highest value in Grdarasha (154.03 and 123.77 pod plant^{-1}) was recorded for (super Nano * Brazowe cultivar) and (TSP * Brazowe) for both locations respectively. This may be due to the reasons mentioned before.

Table 5 Effect of type of fertilizers, cultivars and their interactions on number of pod plant $^{-1}$.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	76.48 f	89.28 ef	82.88c	
	KCI	85.65ef	115.05 cde	100.35bc	SE
	Urea	85.28ef	145.15 ab	115.21ab	(F) = 6.59
	Agriculture sulfur	109.22 cde	120.05 bcd	114.63ab	
	Triple super phosphate	90.48 ef	136.93 abc	113.70ab	
	Super Nano-fertilizer	97.81def	154.03 a	125.92 a	SE (F*C)
	Nano NPK	86.83 ef	149.66 a	118.25ab	= 9.32
	Mean of cultivars	90.25 b	130.02 a	SE (C) = 3.52	

Grdmala field	Fertilizers treatments	Libra	Brazowe	Mean of fertilizers	
	Control	100.75^{cd}	98.23^{d}	99.49^{b}	
	KCI	116.58 ^{abc}	108.12 $^{a-d}$	112.35^{a}	
	Urea	113.07 $^{a-d}$	115.77^{abc}	114.42^{a}	SE
	Agriculture sulfur	102.02 ^{bcd}	115.98 ^{abc}	109.00^{ab}	(F) = 3.32
	Triple super phosphate	108.88^{a-d}	123.77^{a}	114.82^{a}	
	Super Nano-fertilizer	101.74^{bcd}	116.03 ^{abc}	108.89^{ab}	
	Nano NPK	117.69 ^{abc}	118.97 ^{ab}	118.33^{a}	SE (F*C)
	Mean of cultivars	108.25^{b}	113.84^{a}	SE (C) =1.77	= 4.69

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Pod weight (g plant^{-1}): Table 6 revealed that application of types of fertilizers had significant effect on the pod weight per plant. The highest mean value of pod weight per plant was 6.88 and 8.70 g was founded from the application of foliar triple super phosphate fertilizer as compared to control treatment which was 4.43 and 5.59g for both locations respectively then increase in their weight. This may be due to the role of phosphorus in pod formation. It corroborated the findings of (11) they indicated that high yielding varieties of linseed respond well to moderate dose of fertilizers, as well as to (24) that application of recommended dose of fertilizers would be helpful in realizing yield potential of the linseed varieties.

The studied cultivars affected significantly on the weight of pods per plant table 6. The maximum mean value 6.83 and 8.01 g plant^{-1} was recorded for Brazowe and the lowest value 4.55 and 7.13 g plant^{-1} was obtained from Libra cultivars at Grdarasha and Grdmala respectively. This result agrees with (10) who observed that the differences among cultivars significantly affected on weight of pods per plant. The difference also may be due to genetically factor.

Table 6 explained that there was a significant effect of interaction treatments on pod weight per plant. The maximum mean value (8.05 and 9.33 g plant^{-1}) was observed from interaction treatments of (Brazowe * Super Nano fertilizer) and (Brazowe * TSP) for both locations respectively, and the lowest value 3.51 and 5.50 g was obtained from interaction treatment of (Libra * Control) for both locations respectively. This may be due to the single effect of the studied factors and the interaction between them may create the different growth conditions then obtaining different results (12).

Table 6 Effect of types of fertilizers, cultivars and their interactions on the pod weight per plant.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	3.51 e	5.34 d	4.43 d	
	KCI	3.48 e	5.74 cd	4.61 d	SE
	Urea	3.76 e	7.73 a	5.75 bc	(F) = 0.32
	Agriculture sulfur	7.03 abc	6.21 bcd	6.62 ab	
	Triple super phosphate	6.34 bcd	7.42 ab	6.88 a	
	Super Nano-fertilizer	2.47 e	8.05 a	5.26 cd	SE (F*C)
	Nano NPK	5.25 d	7.29 ab	6.27 ab	= 0.45
	Mean of cultivars	4.55 b	6.83 a	SE (C)= 0.17	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	5.50 d	5.67 cd	5.59 c	
	KCI	8.11 a-d	8.24 a-d	8.18 ab	
	Urea	7.57 a-d	8.20 a-d	7.89 ab	SE
	Agriculture sulfur	6.32 bcd	8.80 ab	7.56 ab	(F) = 0.51
	Triple super phosphate	8.07 a-d	9.33 a	8.70 a	
	Super Nano-fertilizer	5.99 bcd	7.71 a-d	6.85 bc	
	Nano NPK	8.37 abc	8.10 b-e	8.24 ab	SE (F*C)
	Mean of cultivars	7.13b	8.01 a	SE (C)=0.28	= 0.73

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Number of seeds per pod: Table 7 shows that the number of seeds per pod significantly affected by application of different fertilizers. The highest number of seeds (8.41 and 8.55 seeds pod^{-1}) was recorded from application of TSP and KCl or urea fertilizers for both locations respectively, while the lowest values were obtained from control treatment (Table 7). The results of field experiments and soil analysis indicated to low concentration of available nutrients (N, P, and K …. etc). These results agree with (29) whom indicated to application of N, P and K to the studied calcareous soils in Erbil governorate due to high calcium carbonate content which causes low availability of most of essential nutrients for plants.

The differences between cultivars affected significantly on number of seeds the maximum value (8.16 and 8.51 seeds pod^{-1}) was recorded for Brazowe cultivar at both locations respectively. Moreover, lowest values 8.01 and 8.43 were observed for Libra cultivar for both locations respectively. The results are in accordance to those revealed by (8) reported that higher number of seeds per pod 6.71 was observed from Oliwin cultivar as compared to Szafir cultivar. The results were corroborated with the findings of (30) they found that the maximum number of capsules per plant and numbers of seeds per capsule were found to be significantly under variety LC 2063 as compare to other cultivars.

The interaction between fertilizers and cultivars had significant influence on the number of seeds per pod. The highest mean value (8.51and 8.65 seed per pod) was recorded for interaction treatment of (Libra * triple super phosphate) at both locations respectively. On the other hand, the lowest value for both locations was recorded from interaction treatment of (Libra * Control) in Table 7.

Table 7 Effect of types of fertilizers, cultivars and their interactions on number of seeds per pod.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	7.69 de	7.54 e	7.61 c	
	KCI	8.10 a-d	8.16 a-d	8.12 ab	SE
	Urea	8.38 ab	8.01 bcd	8.20 ab	(F) = 0.10
	Agriculture sulfur	8.28 abc	8.16 a-d	8.22 ab	
	Triple super phosphate	8.51 a	8.30 abc	8.41 a	
	Super Nano-fertilizer	7.84 cde	8.05 a-d	7.95 b	SE (F*C)
	Nano NPK	8.32 abc	7.84cde	8.08 b	= 0.15
	Mean of cultivars	8.16 a	8.01 b	SE(C)= 0.05	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	8.22 e	8.26 de	8.24 b	
	KCI	8.55 ab	8.55 ab	8.55 a	
	Urea	8.59 ab	8.52 abc	8.55 a	SE
	Agriculture sulfur	8. 16 bcd	8.51 abc	8.48 a	(F) = 0.04
	Triple super phosphate	8.65 a	8.33 cde	8.49 a	
	Super Nano-fertilizer	8.51 abc	8.57 ab	8.54 a	SE (F*C)
	Nano NPK	8.57 ab	8.300 de	8.44 a	= 0.06
	Mean of cultivars	8.51 a	8.43 b	SE(C)= 0.02	

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Seed index (weight of 1000- seeds): Data in table 8 indicated that the application of fertilizers affected significantly on seed index (weight of 1000 seeds). The highest mean value of seed index at Grdarasha was 5.14g which obtained from application of triple super phosphate fertilizer as compared to the lowest value 4.26g observed from control treatment. Whereas, in the second location (Grdmala) the highest mean value 6.67g was recorded by application of Urea fertilizer, as compared to control treatment these findings are supported by those reported by (9) who found that adequate supply of phosphorus enhanced seed production of flax. This results also agreement with (34). This may be application of urea in this location caused nutrient balance more than other treatments. (35) found that urea significantly exceeded ammonium sulfate in both seed index and seed yield ha^{-1} and increasing rates of N and P improved seed index (1000-seed weight).

In contrast, it was noticed that the cultivar had a significant effect on 1000- seed weight. The 1000 seed weight of Libra 5.21g was superior to that of Brazowe 4.53g in Grdarasha location. Conversely, the maximum value 5.65 for Brazowe and minimum value 5.56 for Libra was noted at Grdmala location. The current results are in accordance to those reported by (6) who reported the significant effect of cultivars on 1000- seed weight.

Seed index were affected significantly by the interaction between fertilizer and cultivars. The maximum mean value 5.74 was founded at Grdarasha from the interaction treatment of (Libra * TSP), as compared to control treatment. In contrary, in the second location the highest value 6.74g was obtained from interaction treatment of (Brazowe * Urea) and the lowest value 4.07g from interaction treatment of (Brazowe * Control). These results agree with (22) and (19). The above results may be due to the reasons mentioned before.

Table 8 Effect of type of fertilizers, cultivars and their interactions on the weight of 1000- seed.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	4.08 ^{f}	4.45 ^{ef}	4.26 ^{c}	
	KCI	5.22 ^{abc}	4.90 ^{cde}	5.06 ^{a}	SE
	Urea	5.57 ^{ab}	4.42 ^{ef}	4.99 ^{ab}	(F) = 0.12
	Agriculture sulfur	5.29 ^{abc}	4.54 ^{def}	4.91 ^{ab}	
	Triple super phosphate	5.74 ^{a}	4.54 ^{def}	5.14 ^{a}	
	Super Nano-fertilizer	5.54 ^{ab}	4.57 ^{def}	5.05 ^{a}	SE (F*C)
	Nano NPK	5.06 ^{bcd}	4.28 ^{f}	4.67 ^{b}	= 0.16
	Mean of cultivars	5.21 ^{a}	4.53 ^{b}	SE (C) = 0.61	
Grdmala field	**Fertilizers treatments**	**Libra**	**Brazowe**	**Mean of fertilizers**	
	Control	4.66 ^{de}	4.07 ^{e}	4.36 ^{c}	
	KCI	4.10 ^{cde}	6.27 ^{abc}	5.63 ^{b}	
	Urea	6.61^{ab}	6.74 ^{a}	6.67 ^{a}	SE
	Agriculture sulfur	6.15 $^{a-d}$	5.52 $^{a-e}$	5.83 ^{ab}	(F) = 0.30
	Triple super phosphate	5.16 $^{b-e}$	5.92 $^{a-d}$	5.54 ^{b}	
	Super Nano-fertilizer	5.70 $^{a-d}$	4.63 ^{de}	5.17 ^{bc}	
	Nano NPK	5.64 $^{a-d}$	6.43 ^{abc}	6.04 ^{ab}	SE (F*C)
	Mean of cultivars	5.56 ^{a}	5.65 ^{a}	SE (C) = 0.16	=0.43

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Effect of type of fertilizers, cultivars and their interactions on yield parameters Seed yield g plant^{-1}: Table 9 indicates to significant effect of type of fertilizers, cultivars and their interactions on seed yield per plant at both locations. The highest seed yield

for Grdarasha and Grdmala locations were 4.65 add 6.27 g plant^{-1}, which were recorded from Nano NPK for both locations respectively. This may be due to the role of Nano-NPK in increasing number of secondary branch and number of pod plant $^{-1}$ Table 4 and 5, while the lowest values were 2.58 and 4.45 g plant^{-1} for both locations respectively that were recorded from control treatment.

The cultivars affected significantly on seed yield, the Brazowe cultivar recorded the highest seed yield per plant which were 4.42 and 5.86 g plant $^{-1}$ for both locations respectively, while the lowest values were 2.94 and 5.34 g plant $^{-1}$ that recorded from Libra cultivar at Grdarasha and Grdmala location respectively.

The interaction treatments of (super Nano * Brazowe cultivar) and (TSP * Brazowe) were recorded the highest seed yield per plant which were 5.97 and 6.99 g plant^{-1} ,while the lowest values 2.20 and 4.34 g plant $^{-1}$ were obtained from interaction treatment (Control * Libra) for both locations respectively .The superior of super Nano fertilizer and TSP may be due to low availability of phosphorus in both locations due to high calcium carbonate content of the soil for both locations also the available phosphorus at both locations was not adequate for high yield table1. In general, at Grdmala location the yield was higher than Grdarasha location, this may be due to the higher depth of rainfall and higher soil fertility at Grdmala location in comparing with Grdarasha location as mentioned before Table,1 and Figure 1 and 2.

Table 9 Effect of type of fertilizers, cultivars and their interactions on seed yield (g plant^{-1}).

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	2.20^{d}	2.96^{cd}	2.58^{c}	
	KCI	2.56^{cd}	3.63^{bcd}	3.10^{bc}	SE
	Urea	2.94^{cd}	4.86^{ab}	3.90^{ab}	(F) = 0.37
	Agriculture sulfur	3.66^{bcd}	4.02^{bc}	3.84^{ab}	
	Triple super phosphate	3.48^{bcd}	3.66^{bcd}	3.57^{abc}	
	Super Nano-fertilizer	2.36^{cd}	5.97^{a}	4.16^{ab}	SE (F*C)
	Nano NPK	3.36^{bcd}	5.93^{a}	4.65^{a}	= 0.53
	Mean of cultivars	2.94^{b}	4.42^{a}	SE(C) =0.2	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	4.34^{e}	4.56^{de}	4.45^{c}	
	KCI	5.40^{b-d}	5.98^{a-d}	5.69^{ab}	
	Urea	5.80^{a-e}	6.12^{abc}	5.96^{ab}	SE
	Agriculture sulfur	4.92^{cde}	6.09^{abc}	5.50^{ab}	(F) = 0.31
	Triple super phosphate	5.19^{cde}	6.99^{a}	6.09^{ab}	
	Super Nano-fertilizer	4.92^{cde}	5.53^{b-e}	5.22^{bc}	
	Nano NPK	6.82^{ab}	5.72^{a-e}	6.27^{a}	SE(F*C)
	Mean of cultivars	5.34^{b}	5.86^{a}	SE(C)=0.16	= 0.43

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Effect of type of fertilizers, cultivars and their interactions on biological yield (g plan[1]): Table 10 refers to significant effect of type of fertilizers, cultivars and their interactions on biological yield of flax at both locations. The highest values 24.58 and 20.75 g plant^{-1} for Grdarasha and Grdmala locations were obtained from application of Urea and Nano-NPK fertilizers respectively, while the lowest values were 16.99 and 14.19 g plant^{-1} for both locations that were recorded from control treatment respectively.

The Brazowe cultivar recorded the highest biological yield per plant were 22.73 and 21.32 g plant $^{-1}$ for both locations respectively, while the lowest values were 18.78 and 14.90 g plant $^{-1}$ which were recorded from Libra cultivar at both locations respectively.

The interaction treatments of (Urea* Brazowe) and (agriculture Sulfur * Brazowe) were recorded the highest biological yield per plant which were 28.42 and 25.75 g plant^{-1}, while the lowest values 16.23 and 12.13 g plant^{-1} were observed from interaction treatment (Control * Libra) for both locations respectively. The variation between the levels of the studied factor and their interactions may be due to the single effect of the studied factors and the interaction between them may create different conditions for plant growth which caused the significant differences between them (12).

Table 10 Effect of fertilizer types, cultivars and their interactions on biological yield (g plant^{-1}).

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	16.23^{c}	17.75^{c}	16.99^{c}	
	KCI	16.79^{c}	20.88^{abc}	18.84^{bc}	SE
	Urea	20.75^{abc}	28.42^{a}	24.58^{a}	(F) = 1.68
	Agriculture sulfur	17.88^{c}	19.42^{c}	18.65b^{c}	
	Triple super phosphate	19.00^{c}	20.13b^{c}	19.56^{abc}	
	Super Nano-fertilizer	17.46^{c}	28.25^{ab}	22.86^{ab}	SE (F*C)
	Nano NPK	23.38^{abc}	24.25^{abc}	23.81^{ab}	= 2.37
	Mean of cultivars	18.78^{b}	22.73^{a}	SE(C) = 0.90	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	12.13^{g}	16.25^{efg}	14.19^{c}	
	KCI	13.17^{g}	18.63^{c-f}	15.90^{bc}	
	Urea	14.92f^{g}	25.75^{a}	20.33^{a}	SE
	Agriculture sulfur	22.00^{a-d}	19.13^{b-f}	20.56^{a}	(F) = 1.22
	Triple super phosphate	12.33^{g}	21.63^{a-e}	16.98^{abc}	
	Super Nano-fertilizer	12.63^{g}	23.50^{abc}	18.06^{ab}	
	Nano NPK	17.13^{d-g}	24.38^{ab}	20.75^{a}	SE (F*C)
	Mean of cultivars	14.90^{b}	21.32^{a}	SE(C)=0.65	= 1.68

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

The superior of urea and Nano-NPK fertilizers may be due to low availability of nitrogen phosphorus and potassium in the soil of both locations due to their high calcium carbonate content, and application of Nano-NPK may cause nutrient balance then increase in biological yield table 1. On the other hand, the environmental condition of the study area may be more suitable for Brazowe cultivar in comparing with Libra due to their variation in genotypic properties. In general, at Grdmala location the biological yield was higher than Grdarasha location; this may be due to the reasons mentioned before.

Harvest index %: Table 11 shows the significant effect of type of fertilizers, cultivars and their interactions on harvest index of flax at both locations. The highest values 20.64 and 37.76 % was recorded from application of Agriculture Sulphur and TSP respectively for both locations respectively. While, the lowest values 15.4 6 and 31.98% were obtained from control treatment at both locations respectively.

The highest harvest index 19.46 and 37.81 % were observed from Brazowe and Libra cultivars at both locations respectively, while the lowest values 16.56 and 28.12 % were recorded from Libra at both locations respectively.

The interaction treatments of (Nano NPK * Brazowe cultivar) and (Nano NPK * Libra) were recorded the highest harvest index which were 24.72 and 42.86 % for both locations respectively, while the lowest values 14.23 and 28.17 % were observed from interaction (Control * Libra) and (Control* Brazowe) for both locations respectively .This may be due to the effect of the studied treatments and their interactions on plant growth and yield as mentioned before and the harvest index depends on the ratio between seed yield and biological yield.

Table 11 the influence of fertilizer types, flax cultivars and their interactions on harvest index.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	14.23^{a}	16.70^{a}	15.46^{a}	
	KCI	16.44^{a}	17.42^{a}	16.93^{a}	SE
	Urea	14.49^{a}	17.16^{a}	15.83^{a}	(F) = 2.12
	Agriculture sulfur	20.61^{a}	20.66^{a}	20.64^{a}	
	Triple super phosphate	19.61^{a}	18.36^{a}	18.93^{a}	
	Super Nano-fertilizer	14.98^{a}	21.18^{a}	18.08^{a}	SE (F*C)
	Nano NPK	15.57^{a}	24.72^{a}	20.14^{a}	= 2.99
	Mean of cultivars	16.56^{a}	19.46^{a}	SE(C)=1.13	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	35.79^{abc}	28.17^{bc}	31.98 ^{ab}	
	KCI	41.14^{ab}	32.13^{abc}	36.64 ^{ab}	
	Urea	40.40^{ab}	24.27^{c}	32.34 ^{ab}	SE
	Agriculture sulfur	22.60^{c}	31.80^{abc}	27.20 ^{b}	(F) = 3.04
	Triple super phosphate	42.46^{a}	33.06^{abc}	37.76^{a}	
	Super Nano-fertilizer	39.43^{ab}	22.58^{c}	31.51 ^{ab}	

	Nano NPK	42.86[a]	23.85[c]	33.36[ab]	SE (F*C)
	Mean of cultivars	37.81[a]	28.12[b]	SE(C)=1.62	= 4.29

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Effect of type of fertilizers, cultivars and their interaction on seed quality:

Effect of type of fertilizers, cultivars and their interaction on oil percentage: Table 12 explains the significant influence of the studied factors and their interactions on seed oil percentage. The highest oil percentage was recorded from application of triple super phosphate and Nano NPK with the value of 28.77 and 32.96 % respectively, for both locations respectively. This may be due to the role of phosphorus in oil formation.

The oil % also affected significantly by cultivars at both locations, the highest value 27.50 and 30.73 % was recorded for Brazowe cultivar and the lowest value 25.93 and 29.95 % was recorded for Libra cultivar at both locations respectively. This may be due to the difference between their genetic properties, and the higher seed oil % at Grdmala location in comparing with Grdarasha location may be due to higher available phosphorus of Grdmala soil in comparing with available phosphorus at Grdarasha soil Table 1.

The interaction treatments also had significant influence on seed oil%, the highest values 30.18 and 33.42 % were recorded from interaction treatments (TSP * Libra cultivar) and (Nano NPK* Brazowe cultivar) for both locations respectively. This may be due to the role of both single factors in additional to the reasons mentioned before.

Table 12 Effect of fertilizer types, flax cultivars and their interactions on oil content.

	Fertilizers treatments (F)	Cultivars (C)		Mean of fertilizers	
		Libra	Brazowe		
Grdarasha field	Control	21.26[b]	24.48[ab]	22.87[c]	
	KCI	25.60[ab]	29.20[a]	27.40[ab]	SE
	Urea	26.42[ab]	28.71[a]	27.56[ab]	(F) = 0.92
	Agriculture sulfur	26.68[ab]	27.89[a]	27.29[ab]	
	Triple super phosphate	30.18[a]	27.35[ab]	28.77[a]	
	Super Nano-fertilizer	25.02[ab]	26.52[ab]	25.77[b]	SE(F*C)
	Nano NPK	26.32[ab]	28.35[a]	27.34[ab]	= 1.3
	Mean of cultivars	25.93[b]	27.50[a]	SE(C)= 0.49	
	Fertilizers treatments	**Libra**	**Brazowe**	**Mean of fertilizers**	
Grdmala field	Control	27.76[c]	27.79[c]	27.77[c]	
	KCI	30.05[abc]	29.85[abc]	29.95[bc]	
	Urea	28.50[bc]	32.65[ab]	30.57[ab]	SE
	Agriculture sulfur	29.71[abc]	32.22[ab]	30.97[ab]	(F) = 0.66

Triple super phosphate	30.60^{abc}	28.95^{bc}	29.77^{bc}	
Super Nano-fertilizer	32.21^{ab}	28.60^{bc}	30.40^{ab}	
Nano NPK	32.50^{ab}	33.42^{a}	32.96^{a}	SE (F*C)
Mean of cultivars	29.95^{b}	30.73^{a}	SE (C) =0.35	= 0.94

Values with different letters within columns indicates significantly differences at 5% of probability according to Duncan's multiple range test.

Conclusion: The flax growth, yield and quality affected by fertilizers, cultivars and their interactions. The Nano-fertilizers were superior traditional chemical fertilizers in their role in increasing yield and quality of flax. The higher values for the studied flax characters were recorded at Grdmala location in comparing with Grdarasha location due to lower calcium carbonate and higher rainfall depth at Grdmala location.

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