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Research Article
Moringa Leaves Extract and Zeatin for Maximizing Yield and Quality Traits of Two Flax Cultivars

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Abstract
Background and Objective: Flax is an ancient crop grown as an oil, fibre and dual-purpose crop for economic purposes. Thus, is it important to increase the flax productivity of flax cultivars under sandy conditions by using different natural compounds such as moringa leaves extract and Zeatin with different concentrations. **Materials and Methods:** In split-plot design, a field experiment was carried out to assess the physiological role of exogenous application of moringa leaves extract at rates of (0, 10, 20 and 30%) and Zeatin at rates of (0, 100, 200 and 300 mg L^{-1}) on growth, some physiological indices, yield and quality traits of two flax (Sakha-1 and Line-4) varieties grown under sandy soils conditions at Researches and Production Station of National Research Centre, Al Nubaria district El-Behira Governorate-Egypt, in two winter seasons. **Results:** Results indicated that line-4 variety surpassed Sakha-1 variety in root dry weight, indole acetic acid content (IAA), plant height, technical stem length, fruiting zone length, seed and biological yields/plant seed, straw, biological and oil yields per feddan, seed oil and carbohydrates (%). Regarding moringa leaves extract application at the rate of 20% surpassed all other treatments in plant fresh and dry weight, root length, root fresh and dry weight and seed yield per plant, 1000 seeds weight and oil (%). Meanwhile, Zeatin treatment with 200 mg L^{-1} surpassed the other used treatments in increasing photosynthetic pigments, IAA, yield and its components as well as carbohydrates (%) in the yielded seeds. **Conclusion:** Furthermore, moringa leaves extract 20% was more effective than 10 and 30% as it caused the highest increases in different studied growth, biochemical and yield parameters in the two tested varieties. Zeatin exogenous treatment with 200 mg L^{-1} was more effective than other treatments on the two tested varieties.

Key words: Flax varieties, production, quality, moringa leaves extract, Zeatin

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Flax (*Linum usitatissimum* L.) is an ancient crop grown as an oil, fibre and dual economic purpose plant. Because of quick air drying oil, it is utilized for making paintings, varnishes, printing ink, oilcloth and soap. It is considered the second fibre plant in Egypt following cotton in respect to the cultivated land in addition to its important role in the national economy attributable to export besides local industry[1]. Currently, the advantages of flax have progressed beyond all predictions. Despite the conventional benefits, this plant has many advantages for livestock feeding. Flaxseed oil is used medicinally due to the increased proportion of α-Linolenic (omega-3) to Linoleic (omega-6) unsaturated fatty acids and it is among the biggest suppliers of omega[2-3].

The flax plant is a winter plant so; its productivity is limited because of the competition with many economic winter plants causing a gap between production and consumption. So, it is important to increase flax production via using different strategies, such as expanding flax cultivation in sandy soil and using the high yielding cultivars or using exogenous treatments of natural compounds. Earlier reports were stated that flax productivity per unit area was increased using high yielding cultivars[3-7].

The perspective of sustainable crop production and increasing agricultural yield with cheap inputs are the demands for farmers, especially small scales ones. This includes several strategies for the exogenous application of different natural compounds. Either pre-soaking treatment or foliar treatment, which do not harm the environment, support and sustain local communities. One of those natural substances which can be supplied safely to crops is Moringa Leaves Extract (MLE) and Zeatin plant growth regulator. Moringa plant is loaded with nutrients such as antioxidants, vitamins, minerals, phytonutrients and proteins. Moreover, Moringa leaves extract being a rich source of Zeatin, ascorbates, carotenoids, phenols, antioxidants and essential plant nutrients, so, it has the ability for modifying plant growth and is also used as an exogenous plant growth stimulator[8-9]. Accordingly, many scientists highlighted the role of its leaves extract (as crop foliar application) on enhancing different crop production. They recorded a significant enhancing effect by moringa foliar application on rocket growth and yield, pea and onion[10-12].

Iqbal[13] reported that foliar spray of moringa leaves extract increased canola growth and yield. Kanchani and Harris[14] reported that moringa leaves extract application improved the growth and yield of okra and it improved the growth rate of young plants. Moreover, leaves extract provides firm stems, increases resistance to biotic and abiotic stresses, extends life span, increases the number of roots, stems and leaves associated with more and larger fruits and generally increases yield[8],[9] by 20-35%. Abdalla[10] indicated that spraying rocket plants with moringa leaves extract improved growth characters, photosynthetic rates, stomatal conductance, gave the highest values of chlorophyll a and b, carotenoids, total protein, total sugars, phenols, ascorbic acid, N, P, K, Ca, Mg, Fe as well as growth-promoting hormones (auxins, gibberellins and cytokinins). In addition, Moringa Leaf Extract (MLE) assumed an appropriate plant growth promoter in different studies[15-16]. Siddhuraju and Becker[17] investigated the antioxidants activities of moringa leaf extract and concluded that it decreased potassium ferricyanide, scavenged superoxide radicals, prevented the peroxidation of lipid membrane in liposome's, could donate hydrogen and scavenge radicals.

Plant Growth Regulators (PGRs) are effective methods used to overcome production challenges. The PGRs are believed to affect plant growth and development at really trace levels meanwhile; at elevated doses, they suppress growth and developmental stage[18]. Furthermore, plant response to PGRs might fluctuate according to varieties, environmental conditions, biochemical and nutritional status, development stage and endogenous hormonal balance[19]of the different PGRs that control plant growth either under normal or adverse environmental conditions are cytokinin. The root is the main site of cytokinin biosynthesis in higher plants, then transferred via the xylem to aerial parts of the plant. These PGRs have an influential role in plant physiology and are closely implicated in the regulation of cell differentiation, apical dominance, chloroplast development, anthocyanin production and maintenance of the source-sinkrelationship[20]. Moreover, cytokinins are known to be the most effective senescence-delaying PGRs and their exogenous treatment was shown to inhibit chlorophyll and photosynthetic proteins destruction and reverse leaf and fruitsenescence[21]. Zeatin is one of this group, it enhances plant growth and production even under environmental stress. It was proposed that Zeatin exogenous treatment could be used in combination with other fertilizers, considering that this PGR cannot function in place of fertilizers but performs better when treated along with other fertilizers. As far as the concentration of Zeatin is concerned it was found that the concentration of Zeatin was broader than that of any other cytokinins[22]. In addition, Zeatin is included in carbohydrates transportation as well as distribution to the sink where more carbohydrates are required to meet the needs of rapidly increasing growth. This was proved by Munoz *et al*.[23] they concluded that the movement of carbohydrates is highly impacted by Zeatin riboside and has less impact on protein movement. Lashari *et al.*[24] investigated to optimize Zeatin level and eventually proposed that the optimal Zeatin level for cotton was 0.5-25 mM that provided the best results.

Thus, this study was carried out to investigate the role of moringa leaves extract and Zeatin foliar application with various levels on growth, yield and quality traits of two flax cultivars grown under sandy soils conditions.

MATERIALS AND METHODS

Study area: Two field experiments were carried out at the experimental station of the National Research Centre, Al Nubaria District El-Behira Governorate-Egypt in 2018/2019 and 2019/2020 winter seasons. The soil of the experimental site was sandy. Mechanical, chemical and nutritional analysis[25] of the experimental soil is reported in Table 1 according to Carter and Gregorich[26].

Preparation of Moringa Leaf Extracts (MLE): Young leaves/branches of moringa were harvested from young full-grown trees located in the experimental station of National Research Centre, Al Nubaria district El-Behira Governorate-Egypt. Fresh leaves harvested from fully matured *Moringa oleifera* trees washed, air-dried and made into coarse powder and distilled water was added to the prepared powder sample to get the required concentration and autoclaved at 121°C, 15 lbs sq^{-1} inch for 20 min. Then the hot extract was filtered through double-layered cheesecloth and it was allowed to cool at 4°C. Then, the filtrate was centrifuged at 5000×g for 15 min and the supernatant was collected and considered as 100% of Moringa Leaf Extract[25]. The extract was diluted by adding distilled water at the concentration of 10, 20 and 30%.

The experimental design was a split-plot design with three replication, where flax cultivars occupied the main plots and Moringa leaves extract foliar application at rates of (10, 20 and 30%) or Zeatin foliar application at rates of (100, 200, 300 mg L^{-1}) were allocated at random in subplots. Flax seeds of Sakha-1 and Line-4 cultivars were sown on the 25th November in both seasons in rows 3.5 m long and the distance between rows was 20 cm apart, plot area was 10.5 m^2 (3.0 m in width and 3.5 m in length). The seeding rate was 2000 seeds m^{-2}. Pre-sowing, 150 kg fed^{-1} of calcium super-phosphate (15.5% P_2O_5) were used. Nitrogen was applied after emergence in the form of ammonium nitrate 33.5% at the rate of 75 kg fed^{-1} in five equal doses. Potassium sulfate (48% K_2O) was added at two equal doses of 50 kg fed^{-1}. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days. Foliar applications of different concentrations of Moringa leaves extract or Zeatin were carried out twice; where plants were sprayed after 30 and 45 days from sowing. Plant samples were taken after 60 days from sowing for measurements of growth characters and some biochemical parameters. Growth parameters in terms of, shoot length (cm), shoot fresh and dry weight (g), roots length (cm), root fresh and dry weight (g). The chemical analysis measured was photo synthetic pigments, Indole Acetic Acid (IAA) and phenolic contents. Flax plants were pulled when signs of full maturity were appeared, then left on the ground to suitable complete drying. Capsules were removed carefully. At harvest, technical stem length (cm), fruiting zone length (cm), plant height (cm), number of fruiting branches/plant, number of capsules/plant, biological yield/plant (g), seed yield/plant (g), biological yield (t fed^{-1}), straw yield (t fed^{-1}), seed yield (kg fed^{-1}) and 1000 seeds weight (g) were recorded on random samples of ten guarded plants in each plot, as well as some biochemical constituents of the yielded seeds as oil (%), carbohydrate (%) and oil yield (kg fed^{-1}).

Table 1: Some physical and chemical characteristics of the experimental soil

Sand		Silt 20-0 (µ %)	Clay<2 (µ %)	Soil texture
Course 2000-200 (µ %)	Fine 200-20 (µ %)			
47.46	36.19	12.86	4.28	Sandy

				Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})			
pH 1:2.5	EC (dS m^{-1})	$CaCO_3$	OM (%)	Na^+	K^+	Mg^+	Ca^{++}	CO_3^-	HCO_3^-	Cl^-	SO_4^-
Chemical analysis											
7.60	0.13	5.3	0.06	0.57	0.13	0.92	1.0	0.0	1.25	0.48	0.89

Available nutrients						
Macro element (ppm)			Micro element (ppm)			
N	P	K	Zn	Fe	Mn	Cu
Nutritional analysis						
52	12.0	75	0.14	1.4	0.3	0.00

Chemical analysis: Photosynthetic pigments contents (chlorophyll a and b and carotenoids) in fresh leaves were estimated using the method of Lichtenthaler and Buschmann[27]. Endogenous indole acetic acid content was extracted and analyzed by the method of Gusmiatv *et al.*[28]. Total phenol content was measured as described by Gonzalez *et al.*[29]. Determination of total carbohydrates of seeds was carried out[30]. The oil of flax seeds was extracted[31].

Statistical analysis: The data were statistically analyzed on split-plotdesign, were subjected to analysis of variance[32] since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was done[33]. Means were compared by using the Least Significant Difference (LSD) at 5%.

RESULTS

Variations between flax varieties

Growth parameters: Different growth parameters (shoot and root length (cm), fresh and dry weight (g) of two flax varieties (Sakha-1 and Line-4) are presented in Table 2. Data showed that there are significant variations ($p \geq 0.05$) in all studied parameters of the two flax varieties. Results revealed the superiority of Sakha-1 variety in shoot length, fresh and dry weight, root length and dry weight. Meanwhile, Line-4 variety was superior in rood dry weight.

Photosynthetic pigments: Data in Table 2 showed the effect of varieties on photosynthetic pigments constituents (chlorophyll a, chlorophyll b, carotenoids and total pigments). Results show the significant differences ($p \geq 0.05$) between the two tested varieties Sakha-1 and Line-4 in photosynthetic pigments constituents. Sakha-1 variety was superior over Line-4 varieties in the contents of different photosynthetic constituents. Sakha-1 (1307.56, 656.6, 359.59, 2323.74) greater than Line-4 variety (1139.6, 619.28, 347.25, 2106.13) in chlorophyll a, chlorophyll b, carotenoids and total pigments respectively.

Endogenous indole acetic acid (IAA) and phenol contents: Regarding endogenous IAA and phenol contents in Table 2 data clearly show the significant difference ($p \geq 0.05$) between the two tested varieties. Line-4 varieties have a greater content of endogenous IAA (59.14) over Sakha-1 variety (43.48). Meanwhile, Sakha-1 (50.43) exceeds Line-4 (46.27) in phenolic contents.

Table 2: Effect of varieties on morphological characters, chemical contents and seed straw, biological yields of flax plants under newly reclaimed sandy soil (Combined data of 2018/2019 and 2019/2020 seasons)

	Cultivars		
Characters	Sakha-1	Line-4	$LSD_{0.05}$
Shoot length (cm)	67.05	63.10	2.11
Fresh wt. (g)	3.80	3.11	0.19
Dry wt. (g)	0.60	0.49	0.03
Root length (cm)	13.24	12.24	0.49
Root fresh wt. (g)	0.47	0.38	0.03
Root dry wt. (g)	0.05	0.07	0.01
Chlorophyll a	1307.56	1139.60	17.48
Chlorophyll b	656.60	619.28	6.19
Carotenoids	359.59	347.25	1.43
Total pigments	2323.74	2106.13	21.46
IAA	43.48	59.14	0.48
Phenolic	50.43	46.27	0.13
Plant height (cm)	77.90	86.67	2.84
Technical stem length (cm)	59.00	62.48	1.58
Fruiting zone length (cm)	18.33	24.19	1.30
No. of fruiting branches/plant	24.95	13.14	2.00
No. of capsules/plant	44.76	32.10	2.47
Biological yield/plant (g)	1.87	4.05	0.29
Seed yield/plant (g)	0.38	0.42	0.04
Biological yield (t fed^{-1})	2.57	2.97	0.00
Straw yield (t fed^{-1})	2.06	2.42	0.01
Seed yield (kg fed^{-1})	513.84	575.82	8.79
1000 seeds wt. (g)	6.95	5.66	0.06
Oil (%)	31.14	33.77	0.55
Carbohydrates (%) in seeds	30.41	32.62	0.41
Oil yield kg fed^{-1}	160.99	195.60	1.33

Yield and yield components: The varietal differences in yield and its components of the two tested flax varieties Sakha-1 and Line-4 are presented in Table 2. Data show significant differences ($p \geq 0.05$) between the two varieties. Results showed that Sakha-1 gave a higher number of fruiting branches, capsules/plant and 1000-seeds weight (g). Meanwhile, line-4 variety gave the highest values of plant height (cm), technical stem length (cm), fruiting zone length (cm), seed and biological yields/plant seed (g), straw (t fed^{-1}), biological (t fed^{-1}) and oil yields per feddan as well as seed oil and carbohydrates (%).

Effect of Moringa leaves extract and Zeatin different concentrations

Growth parameters: Data presented in Table 3 show the effect of foliar treatment with different concentrations of either moringa leaves extract (10, 20 and 30%) or Zeatin (100, 200 and 300 mg L^{-1}) on growth parameters of the flax plant. Different treatments caused significant increases in the studied growth parameters shoot, length, fresh and dry

Table 3: Effect of moringa leaves extract or Zeatin on morphological criteria of two flax cultivars grown under newly reclaimed sandy soil (Combined data of 2018/2019 and 2019/2020 seasons)

		Moringa extract (%)			Zeatin (mg L^{-1})			
Materials	Control	10	20	30	100	200	300	$LSD_{0.05}$
Shoot length (cm)	57.00	62.00	68.83	64.83	68.67	71.33	62.83	2.82
Fresh wt. (g)	2.12	3.03	4.78	3.64	3.16	4.60	2.85	0.41
Dry wt. (g)	0.34	0.48	0.76	0.58	0.50	0.73	0.45	0.06
Root length (cm)	9.67	13.33	15.00	13.83	10.83	14.00	12.50	1.05
Root fresh wt. (g)	0.23	0.43	0.62	0.42	0.36	0.62	0.29	0.06
Root dry wt. (g)	0.04	0.06	0.08	0.06	0.06	0.07	0.06	0.01
Chlorophyll a	905.83	1061.13	1325.14	1229.86	1189.38	1515.34	1338.37	12.50
Chlorophyll b	550.94	621.49	659.95	657.15	639.50	694.04	642.52	11.10
Carotenoids	278.33	328.43	387.12	373.58	350.13	395.83	360.51	4.54
Total pigments	1735.10	2011.04	2372.22	2260.58	2179.01	2605.20	2341.40	19.32
IAA	30.54	44.47	63.86	52.04	38.44	73.84	55.97	0.71
Phenolic	36.20	43.88	50.78	51.55	46.56	58.39	51.11	0.58
Plant height (cm)	70.33	77.67	85.00	81.17	83.00	92.50	86.33	2.85
Technical stem length (cm)	53.00	55.50	63.83	61.83	60.33	66.50	64.17	2.26
Fruiting zone length (cm)	17.33	19.00	24.67	19.33	20.33	26.00	22.17	1.68
No. of fruiting branches/plant	13.33	17.00	22.83	19.00	17.00	23.33	20.83	1.40
No. of capsules/plant	31.00	34.50	48.00	37.67	32.17	49.00	36.67	2.31
Biological yield/plant (g)	1.90	2.45	3.53	2.91	2.31	4.37	3.25	0.39
Seed yield/plant (g)	0.34	0.40	0.49	0.44	0.36	0.40	0.38	0.03
Biological yield (t fed^{-1})	1.46	2.35	3.72	2.30	2.78	3.86	2.93	0.0001
Straw yield (t fed^{-1})	1.17	1.83	3.06	1.76	2.26	3.16	2.42	0.01
Seed yield (kg fed^{-1})	363.26	518.89	655.24	540.06	524.02	699.39	512.94	10.48
1000 seeds wt. (g)	5.77	6.28	6.90	6.36	5.89	6.70	6.20	0.20
Oil (%)	30.01	32.13	33.92	32.85	32.04	33.51	32.76	0.44
Carbohydrates (%) in seeds	29.75	31.08	32.31	32.30	30.68	32.56	31.89	0.42
Oil yield (kg fed^{-1})	109.62	167.40	222.68	178.64	167.39	235.08	167.25	3.93

weight as well as root length, fresh and dry weight as compared with untreated controls. Moringa leaves extract with 20% concentration was the most effective treatment in increasing shoot and dry weight, root length, fresh and dry weight in Table 3. Meanwhile, 200 mg L^{-1} Zeatin gave the highest significant increase in shoot length and root fresh weight.

Photosynthetic pigments, indole acetic acid and phenolic contents: All the applied treatments (moringa leaves extract or Zeatin) showed significant increases in photosynthetic pigment constituents (Chlorophyll a, Chlorophyll b, carotenoids and total pigments), endogenous Indole Acetic Acid (IAA) and phenolic contents as shown in Table 3. Zeatin at the rate of 200 mg L^{-1} treatment showed the highest significant increases in Chlorophyll a, Chlorophyll b, carotenoids, total pigments, IAA, total phenolic, followed by 20% moringa leaves extract as compared with other treatments.

Yield and its components: Table 3 showed the effect of different concentrations of moringa leaves extract (10, 20 and 30%) and Zeatin (100, 200 and 300 mg L^{-1}) foliar treatments on yield and its components of the flax plant. Data clearly show the significant increases in the studied yield attributes in response to different treatments as compared with control plants. Zeatin treatment with 200 mg L^{-1} was the most effective treatment as it caused the highest significant increases in most of the studies to yield parameters (plant height, technical stem length, fruiting zone length, number of fruiting branches and capsules/plant, biological yield/plant, seed, straw and biological yields per feddan and oil (%) and oil (yield/fed). While, treatment of Moringa extract at the rate of 20% surpassed all of the moringa treatments in increasing seed yield per plant, 1000-seeds weight, oil seed (%).

Effect of interaction between flax varieties, moringa leaves extract or Zeatin

Growth parameters: Data in Table 4 illustrates the effect of Moringa leaves extract foliar application at rates of (0, 10, 20 and 30%) or Zeatin foliar application at rates of (0, 100, 200, 300 mg L^{-1}) on growth parameters of both flax varieties (Sakha-1 and Line-4) grown under sand soil. Results reported in Table 4 showed that there were significant increases in all growth parameters due to all concentrations used of all

Table 4: Effect of moringa leaves extract or Zeatin on morphological criteria of two flax cultivars Sakha-1 and Line-4 at 75 days after sowing (Combined data of 2018/2019 and 2019/2020 seasons)

	Shoot length (cm)		Fresh weight (g)		Dry weight (g)		Root length (cm)		Root fresh weight (g)		Root dry weight (g)	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4
Control	56.00	58.00	2.40	1.85	0.38	0.29	9.33	10.00	0.21	0.26	0.04	0.05
Moringa extract (%)												
10	58.00	66.00	3.59	2.47	0.57	0.39	14.67	12.00	0.47	0.39	0.04	0.07
20	66.67	71.00	3.93	5.63	0.62	0.89	17.67	12.33	0.56	0.69	0.07	0.10
30	65.00	64.67	3.90	3.39	0.62	0.54	11.33	16.33	0.55	0.30	0.05	0.07
Zeatin (mg L^{-1})												
100	77.33	60.00	3.95	2.37	0.63	0.38	10.33	11.33	0.42	0.30	0.04	0.07
200	80.00	62.67	6.00	3.20	0.95	0.51	15.67	12.33	0.82	0.42	0.06	0.08
300	66.33	59.33	2.83	2.87	0.45	0.46	13.67	11.33	0.27	0.30	0.05	0.06
LSD 5%	3.27	0.79	0.08	1.21	0.01	0.004						

Table 5: Effect of Moringa extract or Zeatin foliar application on photosynthetic pigments, IAA (μg g^{-1} fresh weight), total phenol (mg/100 g fresh weight) of two flax cultivars at 75 days after sowing (Combined data of 2018/2019 and 2019/2020 seasons)

	Chlorophyll a		Chlorophyll b		Carotenoids		Total pigments		IAA (μg g^{-1} fresh weight)		Phenolic	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4
Control	985.5	826.2	577.8	524.1	264.1	292.6	1827.3	1642.9	23.64	37.45	38.01	34.38
Moringa extract (%)												
10	1149.3	972.9	628.9	614.1	332.5	324.4	2110.7	1911.4	33.17	55.78	47.48	40.27
20	1448.4	1201.9	667	652.9	399.6	374.6	2515.1	2229.3	55.93	71.79	54.77	46.8
30	1297.3	1162.4	639.2	675.1	416.4	330.7	2352.9	2168.2	43.02	61.05	49.51	53.59
Zeatin (mg L^{-1})												
100	1243.1	1135.7	659.2	619.8	364.8	335.4	2267.1	2090.9	34.91	41.97	47.77	45.34
200	1575.8	1454.9	739.7	648.4	395	396.7	2710.4	2500	69.7	77.99	59.73	57.05
300	1453.5	1223.2	684.3	600.7	344.7	376.3	2482.6	2200.2	44.01	67.94	55.76	46.47
LSD 5%	14.5	12.9	5.2	22.4	0.8	0.6						

treatments of Moringa extract or Zeatin foliar application. The interaction between Sakha-1 variety and Zeatin foliar application at rates of 200 mg L^{-1} gave the highest values of shoot length, shoot fresh and dry weight, root length, root fresh weight. Meanwhile, Line-4 variety treated with moringa leaves extract with 20% show the highest significant increases in all studied growth parameters.

Photosynthetic pigments, IAA and phenolic compounds: Regarding photo synthetic pigments, endogenous indole acetic acid and phenolic contents of two flax varieties grown under newly reclaimed sandy soil are represented in Table 5. Data show that Moringa leaves extract foliar application at rates of (10, 20, 30%) or Zeatin foliar application at rates of (100, 200, 300 mg L^{-1}) caused significant increases in chlorophyll a, chlorophyll, b, carotenoids and total pigments, IAA and phenolic contents of both flax varieties (Sakha-1 and Line-4) compared with untreated controls. The highest promotive interaction effect was obtained from Zeatin foliar application at rates of 200 mg L^{-1} with Sakha-1 and Line-4 varieties inmost of the tested biochemical parameters compared with other treatments. While moringa leaves extract with 20% concentration was the most effective treatment in chlorophyll b of Line-4 variety and carotenoids content of Sakha-1 variety.

Change in seed yield and yield components: Data presented in Table 6 showed the effect of foliar application at different concentrations of Moringa leaves extract or Zeatin on plant height, technical stem length, fruiting zone length and the number of fruiting branches/plant of two flax varieties (Sakha-1 and Line-4) grown under the newly reclaimed sandy soil. Data clearly show that interaction of moringa leaves extract or Zeatin treatment foliar application with different levels increased significantly the above-mentioned parameters.

Data presented in Table 7 show that interaction of moringa leaves extract or Zeatin treatment foliar application with different levels increased significantly seed yield and its components as the number of capsules/plant, biological

Table 6: Effect of Moringa extract or Zeatin foliar application on two flax cultivars grown under newly reclaimed sandy soil (Combined data of 2018/2019 and 2019/2020 seasons)

	Plant height (cm)		Technical stem length (cm)		Fruiting zone length (cm)		Number of fruiting branches/plant	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4
Control	66.00	74.67	52.67	53.33	13.33	21.33	16.00	10.67
Moringa extract (%)								
10	77.67	77.67	55.33	55.67	16.00	22.00	20.33	13.67
20	77.67	92.33	62.33	65.33	22.33	27.00	29.33	16.33
30	74.67	87.67	59.33	64.33	15.33	23.33	24.67	13.33
Zeatin (mg L^{-1})								
100	80.00	86.00	57.00	63.67	18.33	22.33	22.67	11.33
200	87.33	97.67	64.33	68.67	23.00	29.00	31.67	15.00
300	82.00	90.67	62.00	66.33	20.00	24.33	30.00	11.67
LSD 5%	3.30	2.60	1.90	1.60				

Table 7: Effect of Moringa extract or Zeatin foliar application on yield and yield components of two flax cultivars (Combined data of 2018/2019 and 2019/2020 seasons)

	No. of capsules/plant		Biological yield/plant (g)		Seed yield/plant (g)		Biological yield (t fed^{-1})	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4	Sakha1	Line-4
Control	38.33	23.67	0.87	2.92	0.31	0.37	1.61	1.32
Moringa extract (%)								
10	42.00	27.00	1.68	3.22	0.38	0.41	2.90	1.80
20	53.67	42.33	2.10	4.97	0.48	0.51	3.23	4.21
30	44.33	31.00	1.38	4.44	0.40	0.47	1.79	2.81
Zeatin (mg L^{-1})								
100	40.00	24.33	1.41	3.21	0.34	0.38	2.64	2.92
200	52.33	45.67	3.62	5.12	0.41	0.39	3.18	4.55
300	42.67	30.67	2.05	4.45	0.35	0.41	2.66	3.20
LSD 5%	2.68	0.45	0.04	0.01				

yield/plant (g), seed yield/plant (g) and biological yield (t fed^{-1}). Moringa leaves extract with 20% and 200 mg L^{-1} Zeatin was the most effective treatments in the two tested flax varieties compared with the other used concentrations.

Data presented in Table 8 showed the effect of foliar application at different concentrations of Moringa leaves extract or Zeatin on seed yield and its parameters of two flax varieties (Sakha-1 and Line-4) grown under the newly reclaimed sandy soil. Data clearly show that interaction of moringa leaves extract or Zeatin treatment foliar application with different levels increased significantly straw yield (t fed^{-1}). Seed yield (kg fed^{-1}) and 1000 seed weight (g). Moringa leaves extract with 20% and 200 mg L^{-1} Zeatin was the most effective treatments in the two tested flax varieties compared with the other used concentrations. The increase in yield components of flax in response to different treatments relative to untreated plants might result from the increased number of fruiting branches/plant, the number of capsules/plant and 1000 seed weight (g).

Data presented in Table 9 clearly show that interaction of moringa leaves extract or Zeatin treatment foliar application with different levels increased significantly oil (%), carbohydrates (%) and oil yield (kg fed L^{-1}). Moringa leaves extract with 20% and 200 mg L^{-1} Zeatin was the most effective treatments in the two tested flax varieties compared with the other used concentrations. The maximum increases in and oil yield/fed were obtained in response to the application of Zeatin 200 mg L^{-1} in both flax varieties (Sakha-1 and Line-4).

Rank correlation coefficients: Biological yield/fed, straw yield/fed and/or seed yield/fed of two flax cultivars showed a very strong and positive correlation with all studied traits and yield components, namely shoot length, fresh weight, dry weight, root length, root fresh weight, Chlorophyll a, Chlorophyll b, total pigments, IAA, phenolic content, fruiting zone length, plant height, no. of capsules/plant, 1000 seeds weight and Shoot wt. Biological yield/fed, straw and seed yields/fed. showed non-significant correlation with no. of fruiting branches/plant and 1000-seeds weight and also straw yield/fed, showed non-significant correlation with shoot length in Table 10. This indicates the importance of these traits in the yield and yield component of flax.

Table 8: Effect of Moringa extract or Zeatin foliar application on yield of two flax cultivars (Combined data of 2018/2019 and 2019/2020 seasons)

	Straw yield (t fed^{-1})		Seed yield (kg fed^{-1})		1000 seeds wt. (g)	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4
Control	1.29	1.06	315.0	411.5	6.28	5.26
Moringa extract (%)						
10	2.45	1.21	449.9	587.9	6.86	5.70
20	2.61	3.52	614.5	696.0	7.55	6.25
30	1.35	2.17	433.5	646.7	6.90	5.83
Zeatin (mg L^{-1})						
100	2.07	2.45	571.1	476.9	6.81	4.97
200	2.52	3.81	658.0	740.7	7.40	6.01
300	2.11	2.73	554.8	471.1	6.81	5.58
LSD 5%	0.01	12.1	0.20			

Table 9: Effect of Moringa extract or Zeatin foliar application on oil, carbohydrates (%) and oil yield of two flax cultivars of two flax cultivars (Combined data of 2018/2019 and 2019/2020 seasons)

	Oil (%)		Carbohydrates (%)		Oil yield (kg fed^{-1})	
Treatments	Sakha-1	Line-4	Sakha-1	Line-4	Sakha-1	Line-4
Control	28.71	31.30	28.69	30.82	90.45	128.79
Moringa extract (%)						
10	31.10	33.15	29.98	32.19	139.91	194.89
20	32.82	35.01	30.97	33.65	201.68	243.69
30	31.68	34.01	30.09	34.51	137.32	219.95
Zeatin (mg L^{-1})						
100	30.92	33.16	29.97	31.40	176.62	158.16
200	31.79	35.23	32.06	33.06	209.19	260.96
300	30.97	34.55	31.08	32.70	171.76	162.74
LSD 5%	1.03	1.21	2.33			

Table 10: Rank correlation coefficients between biological (yield/fed), straw (yield/fed) and/or seed (yield/fed) with other studied traits for two flax cultivars (Combined data of 2018/2019 and 2019/2020 seasons)

	Biological (yield/fed)	Straw (yield/fed)	Seed (yield/fed)
Shoot length (cm)	0.28*	0.21	0.59**
Shoot fresh wt. (g)	0.51**	0.48**	0.54**
Shoot dry wt. (g)	0.51**	0.48**	0.54**
Root length (cm)	0.37**	0.33**	0.50**
Root fresh wt. (g)	0.42**	0.39**	0.51**
Root dry wt. (g)	0.62**	0.59**	0.66**
Chlorophyll a	0.62**	0.59**	0.58**
Chlorophyll b	0.51**	0.45**	0.66**
Carotenoids	0.58**	0.55**	0.57**
Total pigments	0.63**	0.59**	0.62**
IAA	0.74**	0.70**	0.81**
Phenolic	0.65**	0.60**	0.68**
Technical stem length (cm)	0.78**	0.76**	0.65**
Fruiting zone length (cm)	0.70**	0.68**	0.75**
Plant height (cm)	0.83**	0.81**	0.73**
No. of fruiting branches/plant	0.09	0.05	0.21
No. of capsules/plant	0.43**	0.41**	0.38**
Biological yield/plant (g)	0.64**	0.63**	0.65**
1000 seeds wt. (g)	0.14	0.11	0.20
Seed yield (kg fed^{-1})	0.45**	0.42**	0.56**
Biological yield (t fed^{-1})	0.99**	0.76**	
Straw yield (t fed^{-1})		0.69**	

**Different significance level

DISCUSSION

The obtained data of varietal differences between Sakha-1 and Line-4 varieties show significant differences between the two flax varieties Sakha-1 and Line-4 in growth parameters, photosynthetic pigments, IAA, Phenols, yield and its components as well as oil and carbohydrates (%) (Table 2). These significant variations between the two flax varieties might result from genetic variations of those varieties, origin and growth habit. Line-4 variety showed more adaptation to sandy soil habitat over Sakha-1 variety and that adaptation reflected on the highest significant value of the seed, straw and biological yields per feddan. In agreement with those obtained data, the results of Afifi *et al.*[3], Kineber *et al.*[34] and Senaratna *et al.*[35] on different plant species. Moreover, the superiority of Line-4 resulted from the increased rate of quenching chlorophyll fluorescence that improved plant growth. Also, seed yield (kg fed^{-1}) superiority of Line-4 variety could be related to increased plant height, fruiting zone length and capsules number/plant, seed yield/plant. The superiority of Line-4 variety in oil yields/fed. maybe resulted from its great number of capsules, the weight of capsules fruiting branches, seed yield/plant, oil (%) (Table 2).

In this study, Moringa leaves extract and Zeatin had similar positive effects on flax plant growth, physiology and productivity. The data documented that Zeatin and moringa leave extract, a putative source of cytokinins[8], increased significantly increases in growth parameters (Table 4). The findings confirm our suggestion that exogenous treatments of moringa leaf extract were considered as growth promotor[36]. Cytokinins among them Zeatin has a crucial effect in promoting cell division, cell elongation and chlorophyll biosynthesis[37].

Chlorophyll a, chlorophyll b, carotenoids and total photosynthetic pigments, IAA, phenolic contents were increased in the two varieties of flax plant as affected by foliar treatments of either moringa leaves extract or Zeatin (Table 5). The current understanding has established that moringa leaves extract contains a significant quantity of plant pigments with documented levels of antioxidant properties such as carotenoids and chlorophyll[38]. Also, MLE contains many macro elements such as magnesium[37]. Mg is a component of chlorophyll, both of which would be demonstrated for the rise in chlorophyll contents. Also, the increased contents of photosynthetic pigments in response to Zeatin resulted from the role of cytokinin preventing pigments degradation and increase biosynthesis.

Different levels of moringa leaves extract either Zeatin caused significant increases in yield and its components as well as (Table 6-8), oil (%), carbohydrate (%) and oil yield (kg fed^{-1}) (Table 9). These results are in good harmony with those obtained by Abusuwar and Abohassan[39] on three cereal forages, Maishanu *et al.*[15] on cowpea, Williams *et al.*[40] on maize. These increases might be attributed to that, moringa leaves extract was demonstrated to contain high amounts of vitamins, antioxidants, high concentrations of inorganic contents, minerals, plant hormones, especially cytokinins. Consequently, it expected to affect positively on growth attributes of different plants. Moringa leaf extract is rich in growth hormones; especially Zeatin that has been reported to increase crop yield[9,41]. It might have plant growth-promoting capabilities, which improved leaf photo synthetic pigments by decreasing the chlorophyll degeneration that increases the growth and yield of a variety of crops ranging from cereals to oil crops, from fibre to sugar crops and from forages to tuber crops[42,43]. They related this promotive effect to Moringa leaf extract being rich in Zeatin, a cytokinin maintained the green photosynthetic area, therefore contributed to higher yield. Regarding Zeatin promotive effect, cytokinins have the strongest effect in preventing leaf senescence either applied exogenously or produced endogenously; delay the leaf senescence by scavenging the free radicals involved in the process of senescence and increase the photo synthetically active leaf area[44] thus increased plant growth and productivity. Phenolic compounds play a key role as protective components of plant cells and protect cells from potential oxidative damage; increase the stability of cell membranes[45]. This increase may be due to total phenols role-playing a significant mechanism in the regulation of plant metabolic processes[46].

CONCLUSION

Variation among the tested applied treatments of moringa leaves extract and Zeatin, was significant for all studied traits. Moringa leaves extract with 20% and 200 mg L^{-1} Zeatin were the most effective treatments in the two flax varieties compared with the other used concentrations. The maximum increases in seed and oil yields/fed were obtained in response to the application of Zeatin 200 mg L^{-1} in both flax varieties (Sakha-1 and Line-4). It is concluded that moringa leaf extract 20% was more effective than 10 and 30% as it caused the highest increases in different studied growth, biochemical and yield parameters in the two tested varieties. Zeatin exogenous treatment with 200 mg L^{-1} was more effective than other treatments on the two tested varieties.

SIGNIFICANCE STATEMENT

This study discovered the physiological effect of natural moringa leaf extract and Zeatin bio regulator treatments on two flax varieties. So, it can be beneficial for researchers and farmers to use natural compounds such as moringa leaf extract and Zeatin to improve the growth and productivity of various plants under sandy soil conditions.

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