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Research article

Effect of interaction between seaweed extract and max unique humate on some vegetative growth indicators of *Linum usitatissimum L.*

Ali Hussein Mohsen[1], Kahraman Hussein Hebeeb[1] and Ahmed Shaker Al-Dahami[2]

[1]*Department of Soil Science and Water Resources, College of Agriculture, Wasit University*
[2]*Department of Field Crops, College of Agriculture, Wasit University, Wasit, Iraq*

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ABSTRACT

This experiment was applied to study the effect of the interaction between seaweed extract and max unique humate on some vegetative growth parameters of flax plants during the 2025-2026 seasons. A randomized complete block design (RCBD) was used as a factorial experiment with three replications at a probability level of 5%. The first factor (seaweed extract) was applied by spraying at four levels (0, 1, 2, and 3) mL/L, designated A0, A1, A2, and A3, respectively. The second factor (max unique humate fertilizer) was applied to the soil at four levels (0, 12, 16, and 20 kg ha^{-1}), designated H0, H1, H2, and H3, respectively. The results showed that the addition of seaweed extract and max unique humate fertilizer significantly affected some vegetative growth indicators, namely (plant height (cm), root system dry weight (g), and chlorophyll content). The significance of the effect increased with increasing levels of added fertilizer. The H3 treatment (20 kg ha^{-1}) yielded the highest values for the studied traits (60.79 cm, 17.57 g, 30.32 g, respectively), compared to the H0 treatment (no addition), which yielded (39.10 cm, 11.97 g, 22.10 g, respectively). Similarly, the A3 seaweed extract (3 ml L^{-1}) yielded (60.37 cm, 16.17 g, 29.72 g, respectively), compared to the control treatment A0 (0 ml L^{-1}), which yielded (38.08 cm). 13.62 g, 22.87 g) respectively. The interaction between the two factors (A3H3) resulted in the highest significant increase in most of the studied indicators, yielding (70.48 cm, 19.09 g, 33.09 g) respectively, compared to the interaction treatment (A0H0), which yielded (31.22 cm, 10.09 g, 20.09 g) respectively.

1. Introduction

The current global trend is to use natural alternatives to mineral fertilizers as supplements rather than replacements. Among these alternatives, seaweed extracts stand out, characterized by their non-polluting and non-toxic properties, in addition to their low cost. These extracts are considered plant growth stimulants, contributing to many essential plant physiological functions. Seaweed contains a variety of macro- and micronutrients, as well as auxins, gibberellins, and cytokinins, which stimulate cell division and elongation in plant tissues. Therefore, using these extracts increases leaf area,

*Corresponding author:
hly081226@gmail.com (Ali Hussein Mohsen)

enhances photosynthetic efficiency, and positively impacts vegetative and root growth indicators. (Abbas, 2017; Begum, 2018).

Seaweed extracts particularly those from brown algae such as *Ascophyllum nodosum*, are a rich source of plant hormones (such as auxins, cytokinins, and gibberellins), amino acids, oligosaccharides, and trace elements. These components work together to stimulate cell division, extend leaf lifespan, improve water use efficiency, and enhance secondary metabolism. These extracts have been shown to activate molecular signaling pathways associated with stress tolerance and may even modulate gene expression via epigenetic mechanisms, including histone modifications linked to defense responses (Shukla et al., 2022; Battacharyya et al., 2023). In this context, interest has grown in the applications of bio- and organic amendments as a safe and effective alternative to conventional chemical inputs. Among the most prominent of these applications are Max Unique, which are natural components resulting from the decomposition of organic matter in the soil. They are known for their ability to improve soil structure, increase water and nutrient retention, and enhance root uptake.

They also act as physiological stimulants, activating enzymes involved in photosynthesis and growth (Chen et al., 2021; Rose et al., 2023). Recent studies have demonstrated that Max Unique enhance plants' ability to withstand oxidative stress by regulating antioxidant defense systems, which is crucial under harsh environmental conditions. It offers multiple benefits in improving the physical properties of the soil (plain density, soil texture, moisture content, porosity) and its chemical properties (lowering soil pH, increasing mineral content and availability, and cation exchange capacity), which is reflected positively in plant growth and yield (Kumar et al., 2024). The documented benefits of both Max Unique and seaweed extracts separately, the scientific understanding of their interaction, particularly in strategic crops like flax, remains limited. This interaction likely produces complementary effects that outweigh those of each treatment alone, through the dual support of physiological functions (such as improved nutrition and hormone activation) and molecular mechanisms (such as modulation of oxidative stress and gene expression).

Flax (*Linum usitatissimum* L.) is one of the oldest oilseed and fiber crops used by human civilizations throughout history. This plant has been utilized for thousands of years in the production of textiles and medicinal and culinary oils. It is characterized by its remarkable adaptability to diverse environmental conditions, which has contributed to its cultivation in vast areas worldwide. It is considered an important economic crop (FAO, 2021). It has unique morphological characteristics, with stems ranging in height from 30 to 120 cm, and its flowers are often blue. Its seeds are characterized by a glossy brown or light-yellow color, depending on the variety. Several researchers have indicated that the physiological properties of flax make it a suitable crop for cultivation in temperate and semi-arid environments (Kumar et al., 2020).

The plant seeds are also distinguished by their high nutritional value, as they are among the richest plant sources of omega-3 fatty acids, especially alpha-linolenic acid (ALA). It also contains a high percentage of fiber and antioxidants, giving it numerous health benefits (Kajlaet et al., 2022). Modern medical research has shown that flax seeds play an important role in promoting heart health, regulating blood lipid levels, and reducing inflammation, thus increasing their nutritional and

therapeutic value (Tauseef et al., 2023). The research aims to study the effect of the interaction between seaweed extract and Max Unique on the growth and yield of flax plants.

2.Materials and Methods

The field experiment was applied in the fields of the College of Agriculture, University of Wasit, to study the effect of the interaction between seaweed extract and Max Unique on some indicators of vegetative growth in flax plants. After preparing the soil by plowing, smoothing, and leveling, the experimental plot was divided into 16 experimental units (4 m^2 per replicate), with a spacing of 20 cm between plants. The experiment was conducted as a factorial experiment using a randomized complete block design (RCBD) on November 1, 2025.

The treatments and their replicates resulted in 48 experimental units. The first factor was seaweed extract (Alga 600) produced by the Chinese company (Dabana) (Table 1), applied by spraying at four levels (0, 1, 2, and 3 ml/L), designated A0, A1, A2, and A3, respectively. The extract was applied in four intervals, with the first application beginning one month after germination, and the interval between applications being 20 days. The second factor is represented by Max Unique (Max Unique Humate 100) produced by the Chinese company City Max, available in four levels (0, 12, 16, and 20 kg ha^{-1}), designated H0, H1, H2, and H3 respectively. The same procedures used with Max Unique were followed regarding the number and timing of applications until the plants reached the flowering stage (50% flowering). The results were statistically analyzed using the Genstst software, and the means for all study indicators were compared using the Least Significant Difference (LSD) test at a probability level of 5% (Al-Sahouki and Wahib, 1990).

Table (1) Components of the fertilizers (Alga 600 and Max Unique Humate 100)

Name of fertilizer	Organic Matter %	Amino Acids %	Potassium	Humic Acid	Fulvic Acid
Alga 600	35	15	17	0	0
Max Unique Humate100	0	0	10	75	15

2.1 Traits studied

Samples were randomly select ten plants from the two middle rows of each treatment and study the following traits:

Plant height (cm): The height of the plant at 100% flowering was measured using a metric ruler from the base of the plant to the end of the main branch.

Dry weight of the root (g): The samples were dried in an oven at 70°C until the weight stabilized. They were then weighed using a sensitive balance. The average dry weight of the root system was calculated by dividing by 5 plants.

Number of fruiting branches (plant^{-1}): This trait was calculated by dividing the number of fruiting branches by the number of plants. 4. Total chlorophyll content in leaves (SPAD): Based on the chlorophyll content at 100% flowering, with an average of five leaves per experimental unit, using a Japanese SPAD 502 apparatus (Reynolds et al., 1889).

2.2 Statistical Analysis:

The results were statistically analyzed using the Genstst software, and the means for all study indicators were compared using the Least Significant Difference (LSD) test at a probability level of 5% (Al-Sahouki and Wahib, 1990).

3. Results and Discussion

3.1 Plant height (cm):

The results indicate a significant effect of the seaweed extract, as treatment (A3) resulted in the highest increase in this trait, reaching 60.37 cm compared to the control (A0). Significant differences were also observed due to the addition of Max Unique in this trait, with treatment H3 (20 kg ha^{-1}) achieving the highest value of 60.79 cm compared to the control (H0). The same table also shows the significant interaction effect between the

seaweed extract and Max Unique on this trait, as the interaction treatment (A3H3) resulted in the highest plant height of 70.48 cm. The height was measured in cm using the control treatment (A0H0), which yielded 31.22 cm (Table 2).

Table (2) effect of the interaction between seaweed extract and max unique humate on plant height (cm)

Max Unique	Seaweed extract				max unique humate average
	A_0	A_1	A_2	A_3	
H0	31.22	35.66	43.88	45.66	39.11
H1	33.48	50.32	54.23	59.23	49.31
H2	40.22	56.24	60.21	66.11	55.69
H3	47.43	60.11	65.15	70.48	60.79
Algal extract average	38.09	50.58	55.87	60.37	---
LSD 0.05	Seaweed extract: 5.92	Max Unique: 5.92		Interference: 8.85	

3.2 Dry weight of the root (g)

The results have been showed that the experimental factors had a significant effect on the dry weight of the flax root system. The treatment with seaweed extract A3 (3 ml L^{-1}) resulted in the highest increase of this trait, reaching 16.17 g, compared to the control (A0), which yielded the lowest value of 10.09 g. Max Unique also significantly affected this trait, with the H3 treatment (20 kg ha^{-1})

producing the highest value of 17.57 g, compared to the control (H0), which yielded 11.97 g. The same table also shows the significant interaction effect between seaweed extract and Max Unique on this trait. The interaction treatment (A3H3) significantly outperformed the control, yielding the highest value of 19.09 g, while the control treatment (A0H0) yielded a value of 10.09 g. (g) (Table 3).

Table (3) Effect of the interaction between seaweed extract and max unique humate on the average dry weight of the root (g)

Max Unique	Seaweed extract				max unique humate average
	A_0	A_1	A_2	A_3	
H0	10.09	12.00	12.25	13.55	11.97
H1	13.50	13.33	14.51	14.43	13.94
H2	14.57	15.08	15.60	17.60	15.71
H3	16.32	17.17	17.70	19.09	17.57
Algal extract average	13.62	14.39	15.02	16.17	---
LSD 0.05	Seaweed extract: 2.33	Max Unique: 2.33		Interference: 4.07	

3.3 Number of branches (Plant^{-1})

Table (4) shows that there is no significant effect of the treatments used on this trait.

Table (4) Effect of the interaction between seaweed extract and max unique humate on the trait of the number of branches

Max Unique	Seaweed extract				max unique humate average
	A0	A1	A2	A3	
H0	14.50	14.71	15.82	15.70	15.18
H1	14.06	14.81	16.04	15.88	15.19
H2	16.91	15.79	17.44	17.60	16.93
H3	17.30	17.77	18.00	18.06	17.78
Algal extract average	15.69	15.77	16.82	16.81	---
LSD 0.05	Seaweed extract: NS	Max Unique: NS		Interference: NS	

3.4 Total chlorophyll content in leaves (Spad)

The results indicate that the experimental factors significantly affected the chlorophyll content of flax leaves. The treatment with seaweed extract A3 (3 ml L^{-1}) resulted in the highest value for this trait, reaching 29.27 (Spad), compared to the control (A0). Max Unique also significantly affected this trait, with the treatment H3 (20 kg ha^{-1}) yielding the highest value of 30.33 (Spad), compared to the

control (H0) which resulted in 22.04 (Spad). The same table also shows the significant interaction effect between seaweed extract and Max Unique on this trait. The interaction treatment (A3H3) resulted in the highest value of 33.09 (Spad), while the control treatment (A0H0) resulted in a value of 20.09. (spad) (Table 5).

Table (5) Effect of the interaction between seaweed extract and max unique humate on total chlorophyll content in leaves (Spad)

Max Unique	Seaweed extract A_0	A_1	A_2	A_3	max unique humate average
H0	20.09	20.89	22.25	24.93	22.04
H1	22.51	26.33	29.51	29.67	27.01
H2	23.57	28.08	30.60	31.21	28.36
H3	25.32	30.17	32.73	33.09	30.33
Algal extract average	22.87	26.37	28.77	29.72	---
LSD 0.05	Seaweed extract: 4.29	Max Unique: 4.29		Interference: 6.98	

It is evident from the above that the A3H3 interaction treatment (3 ml L^{-1} of seaweed extract + 20 kg ha^{-1} of humic fertilizer) significantly increased the values of some of the studied vegetative growth indicators. This may be attributed to the role of Max Unique in increasing cation exchange capacity (CEC), lowering soil pH, and their ability to form natural chelating compounds (due to their content of active hydroxyl, carboxyl, and amine groups). This contributes to increased availability of nutrients and their easy absorption by the roots, thereby increasing their quantity and assimilation within the plant, which positively impacts plant growth (Table 5). Alternatively, the increase may be attributed to the effect of the seaweed extract (Alga600) due to its content of growth-promoting substances such as amino acids and organic acids. It is known that all the aforementioned compounds are involved in protein synthesis and all the important biological processes in the plant that contribute to its growth and development, such as photosynthesis and respiration. This, in turn, is reflected in increased vegetative growth characteristics and yield. (Nobel, 2020; Satish and Lal, 2023).

4. Conclusions

The study concludes that the addition of seaweed extract and max unique humate fertilizer significantly affected some vegetative growth indicators, namely (plant height (cm), root system dry weight (g), and chlorophyll content). The significance of the effect increased with increasing levels of added fertilizer.

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