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Impact of Seaweed Extract and Trichoderma Fungus on Some Traits of Lettuce

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About Article

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ABSTRACT

The study was conducted in the Horticulture Department field located in the Tourist Forest area during the 2024–2025 growing season. It involved three factors: Factor 1: Seaweed Extract (Stimax Nature) Applied in three concentrations: 0 ml L^{-1} (control), 5 ml L^{-1} and 10 ml L^{-1} Factor 2: Trichoderma Fungus (Trichoderma asperellum) Applied at three levels: No fungus (control), 1 g $plant^{-1}$ and 2 g $plant^{-1}$. The fungus was added to the planting hole 10 days before transplanting. Seedlings were then transplanted with the fungus placed beneath the root system of each plant. Factor 3: Lettuce Cultivars>This factor included two imported lettuce cultivars: 'Nader' and 'Fajr'. The experiment included 18 treatments (3 × 3 × 2) in three replicates and was conducted as a field factorial experiment using a Randomized Complete Block Design (RCBD). Treatments were randomly distributed according to the experimental design. The data were statistically analyzed, and treatment means were compared using Duncan's Multiple Range Test at a significance level of ≤ 0.05. The study demonstrates that seaweed extract and Trichoderma fungus can positively influence important lettuce traits, providing a viable pathway for eco-friendly horticultural enhancement, improved productivity, and more sustainable agricultural practices.

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1. INTRODUCTION

Lettuce (*Lactuca sativa* L.) is considered one of the most important vegetable crops belonging to the Compositae family, also known as the Sunflower Family, which is scientifically classified under the family *Asteraceae* (Hassan, 2003). The Compositae is one of the largest families in the plant kingdom, comprising approximately 800 genera and around 20,000 species, most of which are annual herbaceous plants. Lettuce is cultivated for its leaves, which are consumed fresh. It is one of the principal salad crops with significant nutritional and medicinal value. Every 100 grams of lettuce leaves contain the following nutritional components: 49 g moisture, 18 kcal energy, 1.3 g protein, 0.3 g fat, 3.5 g carbohydrates, 0.7 g fiber, 0.9 g ash, 68 mg calcium, 25 mg phosphorus, 1.4 mg iron, 9 mg sodium, 264 mg potassium, 11 mg magnesium, 19 IU vitamin A, 0.05 mg thiamine, 0.08 mg riboflavin, 0.4 mg niacin, and 18 mg ascorbic acid (Kim *et al.*, 2016). Its medicinal value lies in its ability to alleviate chronic constipation due to its cellulose fiber content, which promotes peristalsis. It also helps hydrate the body and acts as a diuretic, especially beneficial for individuals with gout and urinary calculi (Al-Qabbani, 1978). Lettuce is also a significant source of antioxidants such as phenols, which help protect against cancer and cardiovascular diseases. Moreover, it is used to treat skin inflammations and burn pain, as fresh leaves are applied topically as poultices for pain relief and to reduce swelling and inflammation (Lister, 2003). The growth and productivity of lettuce are influenced by several factors, in addition to the prevailing climatic conditions and proper field management practices. This necessitates studying these factors to expand the crop's cultivation and increase productivity per unit area by applying modern agricultural techniques that ensure high yield and quality.

2. LITERATURE REVIEW

Yield enhancement can be achieved through various approaches, such as introducing new imported cultivars, using seaweed extracts, and employing biological control agents like the fungus *Trichoderma*, which plays a crucial role in increasing yield, improving quality traits, maintaining ecological balance, and enhancing the soil's chemical, biological, and physical properties (Kumar *et al.*, 2014). In a study conducted by Di Mola *et al.* (2020) at Gussone Park Experimental Field, Department of Agricultural Sciences in Portici, Southern Italy, lettuce plants were foliar-sprayed with the seaweed extract *Ecklonia maxima* at a concentration of 3 ml·L^{-1}, starting 25 days after transplanting and repeated four times at two-week intervals. The results showed a significant increase in leaf number per plant and marketable yield per unit area compared to untreated plants. Aydin and Demirosy (2020) at Sarayönü University in Turkey applied the seaweed extract Vermiwash at concentrations of 0, 1, 2, and 3 ml·L^{-1} as a single foliar spray two weeks after transplanting. All concentrations significantly increased leaf number, stem weight, and head weight compared to the control (0 ml·L^{-1}). Saeid and Aswad (2023), at the Malta Research Station in Duhok, Iraq, applied *Max Grow* seaweed extract via foliar spray on lettuce three times at concentrations of 0, 3, 6, and 9 ml·L^{-1}. The first spray occurred 10 days after planting, with the second and third sprays 10 days apart. All concentrations led to significant increases in most studied traits, including head weight, head diameter, leaf number, dry matter percentage in leaves, N, P, K content, and total yield compared to the control. Aguiar *et al.* (2024), in Santa Apolónia, Portugal, applied a seaweed extract as a foliar spray during two early growth stages: one week after transplanting and two weeks after the first application at concentrations of 0, 4, and 8 g·L^{-1}. The 4 and 8 g·L^{-1} treatments significantly increased leaf dry matter percentage compared to the control. Opena *et al.* (2022), at Cagayan State University in the Philippines, treated lettuce plants once, 35 days after planting, with a mixture of three seaweed extracts (*Acanthophora spicifera, Gracilaria bursa, Sargassum ilicifolium*) via soil drenching and foliar spraying at concentrations of 5, 10, and 15 ml·L^{-1}. The 5 and 10 ml·L^{-1} treatments significantly increased plant height, marketable head weight, dry matter percentage, and nitrogen and potassium contents in heads compared to 10 ml·L^{-1} alone. Mathieu (2024), in Ngunut Province, evaluated three lettuce cultivars (*Grand Rapid, Karina, Keriebo*) and found that *Grand Rapid* had the highest plant height, leaf number, fresh weight, and average leaf number and height. Sahil and Kumar (2023) in Uttar Pradesh, India, studied five cultivars (*Tango, Bingo, Summer Star, Grand Rapid, Black Rose*) and found that Summer Star produced the highest yield and most traits, while Tango had the highest total chlorophyll content. Kovacsne Madar *et al.* (2022) at the University of Debrecen in Hungary studied three cultivars (*King of May, Romaine, Non-head type*), finding that *King of May* significantly outperformed others in head weight, leaf number, and leaf dry matter content. Avdeenko (2022) in Rostov, Russia, studied six lettuce cultivars (*Moscow Grand House, Abreak, Yearlash, Blues Gascony, Sorvanec*) and found that *Yearlash* had the highest total head yield, dry matter percentage, and marketable head yield. Lima *et al.* (2022) in Brazil found that among three lettuce cultivars (*BAR Lélia, BRS Lélia, BRS Mediterranea*), *BRS Mediterranea* significantly outperformed others in plant height and leaf dry matter content. Ahooi *et al.* (2021) in Iran compared two lettuce cultivars (*Gridelik, Siaho*) and found *Gridelik* superior in leaf number, leaf area, leaf dry matter percentage, total head weight, stem length, and stem circumference. Altintas and Bal (2005) in Turkey observed significant increases in fruit weight, diameter, yield per plant, and greenhouse yield in cucumber when *Trichoderma* was applied at 10 g·m^{-2} compared to 5 and 20 g·m^{-2}. Bal and Altintas (2008) in Turkey showed that applying Trichoderma at 5, 10, and 15 g·m^{-2} to lettuce fields significantly increased plant height, leaf area, head weight, and yield per area compared to no application, with the 15 g·m^{-2} rate being most effective. Ahooi *et al.* (2020) in Iran applied *Trichoderma TBI* to lettuce fields at 5, 10, and 15 g·m^{-2} before transplanting seedlings 40 days after planting. The 5 g·m^{-2} rate significantly increased total leaf number, marketable head weight, leaf dry matter percentage, and stem diameter. Purnawati *et al.* (2021) in Indonesia applied *Trichoderma* at four levels (0, 400, 600, and 700 kg·ha^{-1}) two weeks after transplanting. The treatments significantly increased nitrogen, potassium, phosphorus levels, plant height, leaf number, and head weight. Lima *et al.* (2022) in Brazil applied four *Trichoderma* strains (*T. asperelloides, T. asperellum, T. virens*, and *T. koningiopsis*) to field soil at a concentration of 1.0×10^7 spores·ml^{-1}. The T. virens strain produced the greatest increases in plant height and head weight compared to untreated plants.

3. METHODOLOGY

The experiment was conducted in the vegetable field of the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul, located in the recreational forest area of Mosul City, at a latitude of 36.35° N and a longitude of 43.15° E, with an elevation of 223 meters above sea level, during the 2024–2025 growing season. The land designated for the plastic greenhouse was prepared by plowing with a disc plow, followed by harrowing and leveling using a harrow to achieve a uniform surface. The experimental field was then divided into experimental units. The soil was arranged into three blocks, each comprising three replicates. Each experimental unit measured 1.5 meters in length and 1 meter in width (1.5 m^2 total area), and contained three planting rows per bed. The spacing between rows was 35 cm and between plants was 30 cm, resulting in 15 plants per unit, i.e., 54 plants per treatment. A 50 cm buffer zone was maintained between the experimental units to avoid treatment interference. Seeds were sown on September 25, 2024, in plastic trays containing 50 cells filled with peat moss as the growing medium, inside one of the greenhouses of the Horticulture and Landscape Engineering Department. After sowing, the fungicide "Starter 44 EC" was applied three times at a concentration of 1.5 $L \cdot L^{-1}$ as a preventive spray against insect and mite pests. Once seedlings reached the three to four true leaf stage, they were transplanted on the morning of November 9, 2024, into the greenhouse with great care, ensuring that the peat moss remained around the roots to preserve soil moisture. The experiment studied the effects of three factors on vegetative growth characteristics, yield quantity and quality, and certain chemical traits of lettuce:

Factor 1: Seaweed Extract (Stimax Nature)

Applied at three concentrations: 0 $mL \cdot L^{-1}$ (control), 5 $mL \cdot L^{-1}$ and10 $mL \cdot L^{-1}$

Factor 2: Trichoderma asperellum fungus, applied at three levels: 0 $g \cdot plant^{-1}$ (control, 1 $g \cdot plant^{-1}$ and2 $g \cdot plant^{-1}$

Factor 3: Lettuce Cultivars, involving two imported varieties: 'Nader': and 'Fajr'.

The seaweed extract was applied at four growth stages: the first two weeks after transplanting, followed by three subsequent applications at 14-day intervals. Trichoderma was added to the planting holes 10 days before transplanting. Seedlings were planted such that the fungus was positioned beneath the root zone of each plant. The factorial combinations of the three factors (2 cultivars × 3 fungus levels × 3 extract concentrations) yielded 18 treatments per replicate, with three replicates (54 total treatment plots). Treatments were arranged using a Factorial Experiment in a Randomized Complete Block Design (RCBD). Data were statistically analyzed according to the experimental design, and means were compared using Duncan's Multiple Range Test at a significance level of ≤ 0.05. Statistical analysis was performed using SAS software (2017), based on the methodology of Al-Rawi and Khalaf Allah (2000).

3.1. Studied Traits

i. Chlorophyll Content ($mg \cdot mL^{-1}$ of extract) 2. Plant Height ($cm \cdot plant^{-1}$) 3- Total Leaf Number ($leaves \cdot plant^{-1}$) 3- Total Head Yield ($kg \cdot m^{-2}$).

4. RESULTS AND DISCUSSION

4.1. Chlorophyll content in leaves ($mg \cdot mL^{-1}$)

Table (1) shows that the concentrations of 5 and 10 $mL \cdot L^{-1}$ of seaweed extract significantly outperformed the control. The highest value (9.4041 $mg \cdot mL^{-1}$) was recorded with 10 $mL \cdot L^{-1}$, while the lowest (7.9025 $mg \cdot mL^{-1}$) occurred in the control treatment. As for Trichoderma, the results indicate no significant differences among the levels used. Regarding cultivars, 'Fajr' significantly surpassed 'Nader', recording 9.0753 and 8.3290 $mg \cdot mL^{-1}$ respectively. The interaction between seaweed extract and Trichoderma showed that the combination of 10 $mL \cdot L^{-1}$ extract with 2 g Trichoderma yielded the highest chlorophyll content (10.0978 $mg \cdot mL^{-1}$), while the lowest (6.2853 $mg \cdot mL^{-1}$) was seen in the control treatment (0 $mL \cdot L^{-1}$ extract and 0 g Trichoderma).The interaction between seaweed extract and cultivars also showed superiority of most combinations over the lowest result (7.4259 $mg \cdot mL^{-1}$), observed with 0 $mL \cdot L^{-1}$ extract and 'Nader'. The interaction between Trichoderma and cultivars revealed the highest value (10.0926 $mg \cdot mL^{-1}$) in the treatment combining 2 g Trichoderma with 'Fajr', while the lowest (7.5310 $mg \cdot mL^{-1}$) occurred with 0 g Trichoderma and 'Nader'. Finally, the three-way interaction between seaweed extract, Trichoderma, and cultivars showed the highest chlorophyll content (11.4801 $mg \cdot mL^{-1}$) in the treatment combining 10 $mL \cdot L^{-1}$ extract, 2 g Trichoderma, and the 'Fajr' cultivar. The lowest value (6.0339 $mg \cdot mL^{-1}$) was recorded in the control combination (0 $mL \cdot L^{-1}$ extract, 0 g Trichoderma, and 'Fajr' cultivar).

4.2. Plant height ($cm \cdot plant^{-1}$)

The data presented in Table (2) indicate that there were no significant differences among all levels of the seaweed extract regarding this trait. As for the effect of Trichoderma fungus, the table shows that the highest significant value for plant height was observed at the 1 $g \cdot plant^{-1}$ level, reaching 32.6556 $cm \cdot plant^{-1}$, thus significantly outperforming the higher level of the fungus (2 $g \cdot plant^{-1}$). The results also reveal that no significant differences were observed between the two studied cultivars (Nader and Fajr) in terms of plant height. In the case of the two-way interaction between seaweed extract and Trichoderma, the highest plant height was recorded at 33.5350 $cm \cdot plant^{-1}$ with the interaction of 10 $mL \cdot L^{-1}$ seaweed extract and 1 $g \cdot plant^{-1}$ Trichoderma. This treatment significantly outperformed some other combinations within the interaction. The lowest plant height was observed in the control treatment, at 30.7450 $cm \cdot plant^{-1}$. Regarding the two-way interaction between seaweed extract and cultivars, the results indicate that there were no significant differences among the combinations for this trait. As for the two-way interaction between Trichoderma and cultivars, the data show that the combination of 1 $g \cdot plant^{-1}$ Trichoderma with the 'Fajr' cultivar yielded the highest plant height at 32.8922 $cm \cdot plant^{-1}$, significantly outperforming the combination of 2 $g \cdot plant^{-1}$ Trichoderma with the 'Nader' cultivar, which gave the lowest plant height at 31.2867 $cm \cdot plant^{-1}$.The results of the three-way interaction among the studied factors (seaweed extract, Trichoderma fungus, and cultivars) confirm that the highest plant height was 33.9933 $cm \cdot plant^{-1}$, observed with the combination of 5 $mL \cdot L^{-1}$

seaweed extract, 0 g·plant⁻¹ Trichoderma, and the 'Fajr' cultivar. This combination significantly outperformed some other three-way treatments. In contrast, the lowest plant height, 29.4500 cm·plant^{-1}, was recorded in the control plants grown from the 'Fajr' cultivar.

4.3. Total number of leaves (leaves·plant^{-1})

The results shown in Table (3) indicate that the 5 and 10 mL·L^{-1} concentrations of seaweed extract did not differ significantly from the control (0 mL·L^{-1}) with respect to this trait. Regarding the effect of Trichoderma fungus, the table shows that the highest significant value was recorded at the 2 g·plant^{-1} level, with a mean of 42.7072 leaves·plant^{-1}, while the lowest value was observed in the control treatment (0 g·plant^{-1}) of Trichoderma. There were no significant differences between the two studied cultivars (Nader and Fajr) in terms of this trait. The two-way interaction between seaweed extract and Trichoderma revealed that the highest number of leaves was recorded under the combination of 0 mL·L^{-1} seaweed extract and 2 g·plant^{-1} Trichoderma, reaching 44.350 leaves·plant^{-1}, which significantly outperformed some other interaction treatments. The lowest number of leaves, 38.405 leaves·plant^{-1}, was recorded in the control treatment (0 mL·L^{-1} seaweed extract × 0 g Trichoderma).As for the two-way interaction between seaweed extract and cultivars, the results indicate that no significant differences were found among the combinations for this trait. In the two-way interaction between Trichoderma and cultivars, all combinations significantly outperformed the control level (0 g) of Trichoderma with the Fajr cultivar, which recorded the lowest number of leaves, 38.511 leaves·plant^{-1}.Concerning the three-way interaction among seaweed extract concentrations, Trichoderma levels, and cultivars, the highest number of leaves was observed in the combination of 10 mL·L^{-1} seaweed extract, 0 g Trichoderma, and the Nader cultivar, recording 46.533 leaves·plant^{-1}. Conversely, the lowest number of leaves, 38.643 leaves·plant^{-1}, was obtained under the combination of 0 mL·L^{-1} seaweed extract, 0 g Trichoderma, and the Nader cultivar.

4.4. Total head weight (g·head^{-1})

The data presented in Table (4) regarding the effect of seaweed extract indicate that the concentrations 5 and 10 mL·L^{-1} significantly outperformed the control (0 mL·L^{-1}), which recorded the lowest value for this trait at 755.00 g·head^{-1}. The highest value was observed at the 5 mL·L^{-1} concentration, reaching 823.89 g·head^{-1}.Regarding the effect of Trichoderma fungus, the table shows that the three tested levels of Trichoderma did not differ significantly from each other. Similarly, the two cultivars under study (Nader and Fajr) did not show significant differences in this trait. For the two-way interaction between seaweed extract and Trichoderma, the highest total head weight was recorded at the combination of 5 mL·L^{-1} seaweed extract and 0 g Trichoderma, reaching 881.67 g·head^{-1}. This treatment significantly outperformed most other interaction treatments for this trait. The lowest value, 698.33 g·head^{-1}, was recorded in the control treatment with neither seaweed extract nor Trichoderma applied. Regarding the two-way interaction between seaweed extract and cultivars, the 10 mL·L^{-1} concentration combined with the Fajr cultivar significantly surpassed more than 50% of the interaction treatments, recording 846.11 g·head^{-1}. The lowest value for this interaction was 751.11 g·head^{-1} for the Fajr cultivar treated with 0 mL·L^{-1} seaweed extract. The two-way interaction between Trichoderma and cultivars did not show any significant differences among the interaction treatments for this trait. In the three-way interaction among seaweed extract, Trichoderma, and cultivars, the highest total head weight was observed with the combination of 10 mL·L^{-1} seaweed extract, 1 g Trichoderma, and the Fajr cultivar, reaching 930.00 g·head^{-1}. This treatment significantly outperformed most other three-way interaction treatments for head weight. The lowest value recorded was 673.33 g·head^{-1} in the combination of the Fajr cultivar with 1 g Trichoderma and 0 mL·L^{-1} seaweed extract.

Table 1. Effect of Stimax Nature, Trichoderma fungi , cultivars and interaction between them on chlorophyll content in leaves. (mg ml^{-1} suspension).

Marine extract concentrations (ml^{-1})	Trichoderma fungus levels (g)	Cultivars		Marine extract X Trichoderma fungus	Average impact Marine extract
		Nader	Fajer		
0	0	6.0339 g	6.5366 eg	6.2853 c	7.9025 b
	1	9.5178 a-d	9.4637 a-d	9.4907 ab	
	2	9.5855 a-d	6.2775 f-g	7.9315 b	
5	0	8.4912 bf	9.9915 a-c	9.2413 ab	8.7999 a
	1	10.0282 a-c	7.4762 dg	8.7522 ab	
	2	9.2123 a-d	7.5999 dg	8.4061 b	
10	0	8.1683 cg	10.5347 ab	9.3515 ab	9.4041 a
	1	9.1601 b-d	8.3655 b- f	8.7628 ab	
	2	11.4801 a	8.7155 b-e	10.0978 a	

Marine extract X Cultivars	0	8.3791 ab	7.4259 b	Average impact Trichoderma fungus	
	5	9.2439 a	8.3559 ab		
	10	9.6029 a	9.2052 a		
Trichoderma fungus X Cultivars	0	7.5645 c	9.0209 ab	8.2927 a	
	1	9.5687 ab	8.4351 bc	9.0019 a	
	2	10.0926 a	7.5310 c	8.8118 a	
Average impact of cultivars		9.0753 a	8.3290 b		

**Means that share the same letter for each factor and each interaction are not significantly different from each other according to Duncan's multiple range test at the probability level.)0.05).*

Table 2. Effect of Stimax Nature, Trichoderma fungi, cultivars and interaction between them on plant length (cm.plant^{-1})

Marine extract concentrations (ml^{-1})	Cultivars Trichoderma fungus levels (g)	Cultivars		Marine extract X Trichoderma fungus	Average impact Marine extract
		Nader	Fajer		
0	0	29.4500 d	32.0400 a-c	30.7450 e	31.8700 a
	1	33.3900 ab	31.7467 a-c	32.5683 a-c	
	2	32.1667 a-c	32.4267 a-c	32.2967 a-d	
5	0	33.9933 a	32.8200 a-c	33.4067 ab	32.0533 a
	1	31.8067 a-c	31.9200 a-c	31.8633 b-e	
	2	31.2600 b-d	30.5200 cd	30.8900 de	
10	0	32.4933 a-c	32.3133 a-c	32.4033 a-d	32.5817 a
	1	33.4800 ab	33.5900 ab	33.5350 a	
	2	32.7000 a-c	30.9133 cd	31.8067 c-e	
Marine extract X Cultivars	0	31.6689 a	32.0711 a	Average impact Trichoderma fungus	
	5	32.3533 a	31.7533 a		
	10	32.8911 a	32.2722 a		
Trichoderma fungus X Cultivars	0	31.9789 ab	32.3911 ab	32.1850 ab	
	1	32.8922 a	32.4189 ab	32.6556 a	
	2	32.0422 ab	31.2867 b	31.6644 b	
Average impact of cultivars		32.3044 a	32.0322 a		

**Means that share the same letter for each factor and each interaction are not significantly different from each other according to Duncan's multiple range test at the probability level.)0.05).*

Table 3. Effect of Stimax Nature, Trichoderma fungi , cultivars, and their interactions on the total number of leaves (leaves·plant^{-1}).

Marine extract concentrations (ml^{-1})	Trichoderma fungus levels (g)	Cultivars		Marine extract X Trichoderma fungus	Average impact Marine extract
		Nader	Fajer		
0	0	38,167 d	38,643 cd	38,405 c	41.1406 a
	1	41,733 a-d	39,600 cd	40,667 a-c	
	2	43,300 a-d	45,400 ab	44,350 a	
5	0	38,400 cd	42,067 ad	40,233 bc	42.0628 a
	1	43,833 a-d	44,100 AC	43,967 ab	
	2	43,877 a-d	40,100 b-d	41,988 a-c	

10	0	38,967 cd	46,533 a	42,750 ab	41.5389 a
	1	38,733 cd	41,433 a-d	40,083 bc	
	2	42,733 a-d	40,833 a-d	41,783 a-c	
Marine extract X Cultivars	0	41,067 a	41,214 a	Average impact Trichoderma fungus	
	5	42,037 a	42,089 a		
	10	40,144 a	42,933 a		
Trichoderma fungus X Cultivars	0	38,511 b	42,414 a	40.4628 b	
	1	41,433 a	41,711 a	41.5722 ab	
	2	43,303 a	42,111 a	42.7072 a	
Average impact of cultivars		41.0826 a	42.0789 a		

**Means that share the same letter for each factor and each interaction are not significantly different from each other according to Duncan's multiple range test at the probability level.)0.05).*

Table 4. ffect of Stimax Nature, Trichoderma fungi , cultivars and the interaction between them In total head weight of the plant (g head-1).

Marine extract concentrations(ml^{-1})	Trichoderma fungus levels (g)	Cultivars		Marine extract X Trichoderma fungus	Average impact Marine extract
		Nader	Fajer		
0	0	686.67 gh	710.00 f-h	698.33 f	755.00 b
	1	673.33 h	736.67 e-h	705.00 ef	
	2	893.33 ac	830.00 ae	861.67 ab	
5	0	853.33 ad	910.00 ab	881.67 a	823.89 a
	1	820.00 b- f	788.33 c-g	804.17 bd	
	2	753.33 d-h	818.33 b- f	785.83 cd	
10	0	808.33 b- f	733.33 e-h	770.83 de	798.89 a
	1	930.00 a	766.67 d-h	848.33 a-c	
	2	800.00 b- f	755.00 d-h	777.50 cd	
Marine extract X Cultivars	0	751.11 b	758.89 b	Average impact Trichoderma fungus	
	5	808.89 ab	838.89 a		
	10	846.11 a	751.67 b		
Trichoderma fungus X Cultivars	0	782.78 a	784.44 a	783.61 a	
	1	807.78 a	763.89 a	785.83 a	
	2	815.56 a	801.11 a	808.33 a	
Average impact of cultivars		802.04 a	783.15 a		

**Means that share the same letter for each factor and each interaction are not significantly different from each other according to Duncan's multiple range test at the probability level.) 0.05).*

5. CONCLUSION

The present study clearly demonstrates the beneficial effects of both seaweed extract (Stimax Nature) and Trichoderma asperellum fungus, individually and in combination, on the growth and development of two lettuce cultivars, 'Nader' and 'Fajr'. Across all measured traits, the application of seaweed extract at 10 ml L^{-1} and Trichoderma at 2 g $plant^{-1}$ significantly improved plant performance compared to the control. The synergistic interaction between the highest concentrations of both treatments resulted in the most pronounced positive effects, indicating potential for integrated use in sustainable lettuce production systems.

Importantly, the positive impact was consistent across both lettuce cultivars, suggesting that these biostimulants and biofertilizers could be effectively incorporated into broader crop management strategies. The use of seaweed extract and Trichoderma not only enhanced agronomic traits such as plant vigor and yield components but also supports environmentally sustainable farming by reducing reliance on chemical inputs.

Thus, the implementation of seaweed extract and Trichoderma asperellum in lettuce cultivation offers a promising and eco-friendly approach to improving crop quality and productivity. Further research is recommended to explore the underlying physiological mechanisms and to validate these findings under various environmental conditions and in other horticultural crops.

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