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EFFECT OF HUMIC ACID, SEAWEED EXTRACTS AND ORGANIC FERTILIZER ON YIELD QUALITY OF BROCCOLI (*Brassica oleracea*) GROWN UNDER PLASTIC HOUSE

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ABSTRACT:

The research was carried out at the protected cultivation department in Zakho Technical Institute, Dohuk Polytechnic University, Kurdistan region of Iraq during growing season 2021-2022 aiming to investigate the effect of foliar application of humic acid and seaweed extract each at concentrations (0, 2, and 4) ml.L^{-1} and soil addition of organic fertilizer (animal manure) at three rates (0, 5, and 10) ton.ha^{-1} on yield quality of broccoli cultivar (Agassirz) grown in plastic house. The experiment was designed following a randomized complete block design (RCBD) with three replicates. The earned results showed that the humic acid, seaweed extract, and organic manure, either individually or interacted, caused a prominent amelioration in the head qualitative traits such as Chlorophyll content (SPAD), Total soluble solids (TSS %), Ascorbic acid (%), Vitamin B1 (µg. L^{-1}), and Total carotene (vitamin A) mg. L^{-1} as compared with control. The ever-highest values were obtainable from the treatment: humic acid at (4) ml. L^{-1} + seaweed extract at (4) ml. L^{-1} + organic fertilizer at (10) tons. $donum^{-1}$, which was superior to control and other treatments. The foliar application of humic acid and seaweed extract at a concentration of 4 ml. L^{-1} and soil addition of organic manure at level 10 tons. $donum^{-1}$ is recommended for the organic production of broccoli cultivar (Agassirz).

KEYWORDS: Broccoli, Bio-Stimulants, Organic Manure, Yield Quality

1. INTRODUCTION

Broccoli (*Brassica Oleracea*) belongs to the cruciferous family (*Brassicaceae*), which possesses impressive nutritive and medicinal value. It is well-known to be enriched with numerous bioactive compounds such as carotenoids, niacin, folic acid, riboflavin, and some vitamins, namely E, A, B1, B2, B5, and B6, as well as containing essential nutrients including sodium, iron, calcium, phosphorus, and potassium (Weber, 2017; Al-Birmani, 2017). Some of the bioactive compounds present in Broccoli, particularly glucosinolates and polyphenols, possess antagonistic behavior against cancer and other virulent diseases (Valverde *et al.* 2015; Ordiales *et al.* 2017). Hence, broccoli is beneficial for human health when consumed freshly (Rodriguez Casado 2016). Nowadays, there is an increasing request for new bio-stimulant products to be used in the agricultural sector to attain sustainable production of crops. Plant biostimulants such as humic acid, fulvic acid, seaweed extracts, and amino acids have the potential to improve plant features like growth, abiotic stress endurance, nutritional adequacy, and crop harvest and quality (Du Jardin, 2015). Humic acid is mainly composed of elementary constituents of biodegraded organic matter in the soil, exhibiting biological and chemical impacts on plant outgrowth. They can be directly provided for plants and effectively enriched with carbon, leading to elevated microbial functioning and nutrient obtainability. Such elevation happens via the chelation of nourishing elements and the creation of complex and chelating compounds, resulting in the liberation of free ions, thereby raising the opportunity for uptake in plants (Al Bandawi, 2017). Al-jaf *et al.* (2018) showed that the foliar feeding of humic acid at (2.5) ml.L^{-1} significantly enhanced the yield and quality of the broccoli crop as compared to control. Al-Taey *et al.* (2019) demonstrated that the (Bactrian mixed 20 gm/L + Humic acid 10 ml/L) caused a profound increment in the quality traits of broccoli relative to control. Rachid *et al.* (2020) reported that 4 ml l^{-1} of humic acid in combination with 4 ml l^{-1} of nano-calcium gave the best floral diameter (cm) and floral biochemical content as compared to the control.

Seaweed extract is a modern type of natural organic bio-stimulant that is highly nutritious and, when applied, can effectively impact plant growth and productivity (Battacharyya *et al.*, 2015). This bio-stimulant is enriched with small amounts of macro elements (N, P, K), adequate amounts of microelements as well as organic substances like betaine and betaine like compounds, amino acids, and essential plant growth organizers (auxin, cytokinin, and gibberellins) making it a perfect fertilizer supplement for plant (Begum *et al.,* 2018). Numerous agronomical studies revealed a significant effect on vegetable growth and harvest. Manea and Abbas (2018) showed that the application of seaweed extract at a concentration of 3 mL·L^{-1} significantly enhanced the yield qualitative traits of broccoli in comparison with control. Godlewska *et al.* (2021) unveiled that foliar spraying of botanical extracts, including seaweeds, made a prominent amelioration in vitamin C, carotenoids, and total phenolic substances and reduced the nitrate content in the leaf of the cabbage crop. Mohammed And Sarhan (2023), on broccoli crops, recorded a prominent increment in yield quality attributes such as head length and head diameter.

Organic manure is considered as an alternative natural fertilizer having essential nutrient content required for plant outgrowth and harvest thus ensuring production of food free from chemical residues for human consumption (El-Mesairy *et al.*, 2022). Furthermore, organic manure is consumed as a food supplement by many beneficial microbes and critters like earthworms breaking it down into micronutrients that are already absorbed by plants. The direct influence of organic manure on plant growth is represented by giving off entire necessary macro and microelements in obtainable forms via mineralization,

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leading to a rise in the physical characteristics of the soil (Farid *et al.*, 2023). Many researches displayed a valuable impact of organic manures on the growth and quality of horticultural crops. Saloom *et al.* (2016) inspected the effect of organic, mineral fertilization, and mulching on qualitative attributes of broccoli crops. According to their finding, the binary combination between organic and mineral fertilizers gave the topmost TSS, vitamin C, carbohydrate, and protein in the head. In contrast, the head nitrate content was notably minimized with the same dose. Hammad *et al.* (2019), on broccoli, demonstrated that soil adding of animal manures at a rate of 30 t. ha^{-1} importantly improved head yield and qualitative traits compared to control. Yoldas *et al.* (2020) unveiled that treating broccoli crops with sheep and cattle manure at levels 30 and 60 t ha^{-1} significantly enhanced the whole harvest and head diameter and length. This study aims to investigate the yield and quality response of broccoli crops to the foliar application of two significant bio-stimulants (seaweed extracts and humic acid) and soil addition of organic fertilizer to produce healthy products with fewer costs without causing any pollution to the environment.

2. MATERIAL AND METHODS

The field experiment was implemented in a plastic house (500 m2) at the protected cultivation department in Zakho Technical Institute, Dohuk Polytechnic University, Kurdistan Region/ Iraq, for the growing season (2021-2022). The seeds of the broccoli cultivar (Agassirz) were planted on September 1st inside plate pods filled with peat moss as medium and succeeded by irrigation and germination monitoring. After field irrigation, the seedlings were transplanted in the plastic house field on October 2nd. The space between plants was (50cm) and the line spacing was (60 cm).

The experiment encompassed foliar application of humic acid and algae seaweed extracts, each at three concentrations (0-, 2-, and 4-ml. L^{-1}), and soil application of animal manures at three levels (0, 5, and 10 ton. ha^{-1}) and their combinations. The date of animal manure addition was November 2nd, and the first spraying of both bio-stimulants was performed on November 10th with ten days intervals between three sprays. The experiment was organized in a factorial Randomized Complete Block Design (RCBD) including 81 treatments and 27 experimental units with three replicates. The data were analyzed using (SAS 2010) program and means comparison was done by Duncan's multiple range tests at a 5% level of confidence. The following qualitative characters were measured: head length (cm), head diameter (cm), Total soluble solids (TSS %), Ascorbic acid (%), Vitamin B1 (µg. L^{-1}), and Total carotene (vitamin A) mg. L^{-1}.

3. RESULTS

Head Length (Cm):

The head length of broccoli was significantly influenced by foliar application of humic acid and seaweed extract and soil addition of organic fertilizer and their various treatments. Dosing plants with the humic acid at a concentration of (4) ml.L^{-1} produced the longest heads (18.66 cm) as compared to control (17.49 cm). The seaweed extract sprayed at the same dose (4 ml. L^{-1}) gave the maximum average mean (18.53) cm surpassing the control (17.40) cm. Similarly, the organic manure is applied at a level of (10) tons. $donum^{-1}$ led to the creation of the tallest heads (18.52) cm over the other two treatments.

Meanwhile, the interaction of foliar application of humic acid and seaweed extract both at (4) ml.L^{-1} significantly improved head length (19) cm in comparison with control (16.32) cm. This was also true for the bilateral interaction of humic at (4) ml. L^{-1} and organic fertilizer at 10 tons. $donum^{-1}$, yielding the best average length (19.32) cm, which was superior to other different dual interactions. The highest head length (19.25) cm also resulted from seaweed applied at (4) ml. L^{-1}, in combination with organic manure added at a level of (10) tons. $donum^{-1}$ relative to control (16.43) cm.

On the other hand, the topmost ever head length (20.05 cm) was obtained from humic acid and seaweed extract sprayed at (4) ml. L^{-1} and organic manure fertilized at the level of (10) tons. $donum^{-1}$ against the lowest average value (13.44 cm) being measured for control plants, as demonstrated in Table (1).

Table 1: Effect of humic acid, seaweed extract, and organic fertilizer on head length (cm) of broccoli cultivar (Agarssiz).

Humic acid ml. L^{-1}	Seaweed extract ml. L^{-1}	Organic fertilizer tons. $donum^{-1}$			Humic*seaweed	Humic acid
		0	5	10		
0	0	13.44 ^{d}	17.71 ^{c}	17.80 ^{c}	16.32 d	17.49 ^{b}
	2	17.67 ^{c}	18.83 ^{abc}	17.62 ^{c}	18.04 ^{abc}	
	4	18.23 ^{bc}	18.05 ^{bc}	18.08 ^{bc}	18.12 ^{abc}	
2	0	17.76 ^{c}	17.45 ^{c}	18.16 ^{bc}	17.79 ^{bc}	17.92 ^{b}
	2	17.37 ^{c}	17.61 ^{c}	17.46 ^{c}	17.48 ^{c}	
	4	17.78 ^{c}	18.04 ^{bc}	19.61 ^{ab}	18.48 ^{ab}	
4	0	18.09 ^{bc}	17.37 ^{c}	18.81 ^{abc}	18.09 ^{abc}	18.66 ^{a}
	2	18.74 ^{bc}	18.84 ^{abc}	19.11 ^{abc}	18.90 ^{a}	
	4	18.79 ^{abc}	18.16 ^{bc}	20.05 ^{a}	19.00 ^{a}	
Organic fertilizer		17.54 ^{b}	18.01^{b}	18.52 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	16.45 ^{c}	18.20 ^{b}	17.83 ^{b}		
	2	17.64 ^{b}	17.70 ^{b}	18.41 ^{b}		
	4	18.54 ^{ab}	18.12 ^{b}	19.32 ^{a}		
Seaweed*organic fertilizer	0	16.43^{c}	17.51 ^{b}	18.26 ^{b}	0	17.40 ^{b}
	2	17.93 ^{b}	18.43 ^{ab}	18.06 ^{b}	2	18.14 ^{a}
	4	18.27 ^{b}	18.08 ^{b}	19.25 ^{a}	4	18.53 ^{a}

This means that the same letters are not significantly different from each other.

Head Diameter (Cm):

Data from Table (2) showed that humic acid was individually applied at a concentration of (4) ml. L^{-1} caused a prominent increment in the head diameter (18.73 cm) compared to the other two concentrations. The individual dose of seaweed extract at (4) ml. L^{-1} excelled in the head diameter (18.19 cm). The notable improvement in head diameter (18.29 cm) also resulted from organic fertilizer added at level (10) tons. donum^{-1} relative to the other two levels.

In terms of binary effects, plants treated with humic acid and seaweed extract, both at (4) ml. L^{-1} gave the best average diameter (18.90) cm, exceeding other various doses. The humic acid was provided at (4) ml. L^{-1} interacted with organic fertilizer at (10) tons. donum^{-1} positively affected the head diameter (19.41 cm). In contrast, in the case of (seaweed * organic), the highest average diameter (18.70) cm was gained from foliar feeding of seaweed at (4) ml. L^{-1} and organic fertilizer at level (10) tons. donum^{-1} as matched to control (17.30) cm.

The combination of all factors significantly enhanced head diameter, with the thickest ever head (19.96) cm belonging to plants sprayed with humic and seaweed extract each at a concentration (4) ml. L^{-1} plus organic manure added at (10) tons. donum^{-1} in comparison with the rest of the treatments, as revealed in Table (2).

Table 2: Effect of humic acid, seaweed extract, and organic fertilizer on head diameter (cm) of broccoli cultivar (Agarssiz).

Humic acid ml. L^{-1}	Seaweed extract ml. L^{-1}	Organic fertilizer tons. donum^{-1}			Humic*seaweed	Humic acid
		0	5	10		
0	0	16.89 ^{egf}	16.84 ^{egf}	18.23 $^{e-f}$	17.32 ^{c}	17.52 ^{b}
	2	17.49 $^{e-f}$	17.73 $^{e-f}$	17.03 $^{e-f}$	17.42 ^{c}	
	4	17.90 $^{e-f}$	18.01 $^{e-f}$	17.56 $^{e-f}$	17.82 ^{c}	
2	0	16.91 ^{egf}	16.63 ^{g}	17.99 $^{e-f}$	17.18 ^{c}	17.27 ^{b}
	2	16.46 ^{g}	16.92 $^{e-f}$	16.96 $^{e-f}$	16.78 ^{d}	
	4	17.71 $^{e-f}$	17.23 $^{e-f}$	18.59 $^{e-c}$	17.84 ^{bc}	
4	0	18.11 $^{e-f}$	18.44 $^{e-f}$	19.11 ^{ab}	18.56 ^{b}	18.73 ^{a}
	2	18.31 $^{e-f}$	18.72 $^{b-c}$	19.15 ^{ab}	18.73 ^{ab}	
	4	18.99 ^{abc}	17.76 $^{e-f}$	19.96 ^{a}	18.90 ^{a}	
Organic fertilizer		17.64 ^{b}	17.59 ^{b}	18.29 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	17.42 ^{d}	17.53 ^{cd}	17.61 ^{cbd}		
	2	17.03 ^{d}	16.93 ^{d}	17.84 ^{cbd}		
	4	18.47 ^{b}	18.31 ^{bc}	19.41 ^{a}		
seaweed*organic fertilizer	0	17.30 ^{c}	17.31 ^{c}	18.44 ^{ab}	0	17.68 ^{b}
	2	17.42 ^{c}	17.79 ^{bc}	17.71 ^{bc}	2	17.64 ^{b}
	4	18.20 ^{abc}	17.67 ^{c}	18.70 ^{a}	4	18.19 ^{a}

Means with the same letter are not significantly different from each other3.4.

Total Soluble Solids (TSS %):

The data analysis of TSS displayed that the humic acid at the highest dose (4 ml.L^{-1}) created the peak mean average (8.85) % as matched to control (8.27) %. This significant effect (8.85 and 8.82) % was seen from seaweed extract applied at doses (4) ml.L^{-1} and (2) ml.L^{-1}, respectively, relative to control. The individual level of organic manure at (10) tons. donum^{-1} importantly enhanced TSS, resulting in a maximum mean average of (8.90) %, surpassing the other two levels.

Data also revealed that the bilateral interaction of humic acid and seaweed extract, each at a concentration of (4) ml.L^{-1}, remarkably ameliorated TSS content (9.11) % in comparison with control (7.66) % and other doses. The humic and organic fertilizer interaction also showed supremacy in giving the topmost value (9.01) % when plants were treated with humic acid at (4) ml. L^{-1} and manure at level (10) tons. donum^{-1} as compared to other various treatments. In terms of a combination of seaweed-organic, plants received seaweed extract at (4) ml. L^{-1} and manure at (10) tons. donum^{-1} contained the greatest amount of TSS (9.62) % over control (7.80) %.

On the other hand, the triple interaction of the studied factors gave the ever-peak value (10.13) %, which belonged to plants foliar provided with humic acid and seaweed extract both at a concentration (4) ml. L^{-1} and organic manure were added to the soil at (10) ton.donum^{-1} compared with the least content (7.00) % that was measured in control plants as illustrated in the table (3).

Table 3: Effect of humic acid, seaweed extract, and organic fertilizer on total soluble solids (TSS) % of broccoli cultivar (Agarssiz)

Humic acid ml.L^{-1}	Seaweed extract ml. L^{-1}	Organic fertilizer tons. donum^{-1}			Humic*seaweed	Humic acid
		0	5	10		
0	0	7.00 ^{h}	7.77 $^{e-f}$	8.23 $^{e-f}$	7.66 ^{c}	8.27 ^{b}
	2	8.60 $^{e-f}$	9.57 ^{ab}	8.90 $^{e-f}$	9.02 ^{a}	
	4	7.23 ^{h}	7.90 $^{e-f}$	9.23 $^{e-f}$	8.12 ^{b}	
2	0	7.21 ^{h}	7.67 ^{hg}	8.80 $^{e-f}$	7.89 ^{b}	8.63 ^{ab}
	2	8.37 $^{e-f}$	9.07 $^{e-f}$	8.70 $^{e-f}$	8.71 ^{b}	
	4	9.43 $^{b-c}$	9.00 $^{e-f}$	9.50 ^{ac}	9.31 ^{a}	
4	0	8.70 $^{e-f}$	9.47 $^{b-c}$	7.97 $^{e-f}$	8.71 ^{b}	8.85 ^{a}
	2	9.37 $^{e-c}$	8.17 $^{e-f}$	8.63 $^{e-f}$	8.72 ^{ab}	
	4	7.80 $^{e-f}$	9.40 $^{b-c}$	10.13 ^{a}	9.11 ^{a}	
Organic fertilizer		8.19 ^{b}	8.67 ^{ab}	8.90 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	8.27 ^{b}	8.58 ^{ab}	8.91 ^{a}		
	2	7.84 ^{b}	8.41^{b}	8.79 ^{ab}		
	4	8.62 ^{ab}	9.00 ^{b}	9.01 ^{a}		

Seaweed*organic fertilizer	0	7.80 ^{c}	8.30 ^{bc}	8.33 ^{bc}	0	8.14 ^{b}
	2	8.78 ^{ab}	8.93 ^{ab}	8.74 ^{b}	2	8.82 ^{a}
	4	8.16 ^{c}	8.77 $_{ab}$	9.62 ^{a}	4	8.85 ^{a}

This means that the same letters are not significantly different from each other.

Ascorbic Acid (%):

The broccoli crop significantly responded to the foliar application of humic acid and seaweed extract, and soil application of organic fertilizers, respectively, to ascorbic acid content. The humic acid sprayed at the increased dose (4 ml. L^{-1}) increased the content of ascorbic acid (5.91) % relative to the control (5.43) %. The seaweed extract given at the same concentration also had a prominent effect on ascorbic acid (5.89) % against control (5.41) %. In the status of organic fertilizer effect, the highest ascorbic acid content (5.80) % was measured for plants that have had organic manure at (10) tons. donum^{-1} exceeding the other two levels.

The results indicated a profound impact of dual interferences of factors on ascorbic acid. Plants delivered the humic acid and seaweed at a concentration of (4) ml.L^{-1} led to the production of the best average value (6.32) % in comparison with the remaining treatments. Moreover, the humic acid at (4) ml. L^{-1} plus organic manure at (10) tons. donum^{-1} made the highest average content (6.34) % of ascorbic acid over the control (5.05) %. In the state of seaweed * organic effect, the greatest average content (6.30) % was recorded in plants applied with seaweed at (4) ml. L^{-1} and organic manure at (10) tons. donum^{-1}.

The complex dose; humic acid (4 ml. L^{-1}), seaweed extract (4 ml. L^{-1}), and organic manure (10 tons. donum^{-1}) exhibited superiority and produced the utmost content (7.75) % while the lowest average content (4.52) % was estimated for plants did not dose with any factor as obvious in the table (4).

Table 4: Effect of humic acid, seaweed extract, and organic fertilizer on ascorbic acid (%) of broccoli cultivar (Agarssiz)

Humic acid ml.L^{-1}	**Seaweed extract ml. L^{-1}**	**Organic fertilizer tons. donum^{-1}**			**Humic*seaweed**	**Humic acid**
		0	5	10		
0	0	4.52 ^{h}	5.72 $^{f-g}$	5.99 $^{c-d}$	5.41 ^{cd}	5.43 ^{b}
	2	4.97 $^{f-g}$	5.08 $^{f-g}$	4.87 ^{hg}	4.97 ^{d}	
	4	5.66 $^{f-g}$	6.76 ^{b}	5.33 $^{f-g}$	5.92 ^{ab}	
2	0	5.90 $^{f-d}$	4.48 ^{h}	4.47 ^{h}	4.95 ^{d}	5.44 ^{b}
	2	5.72 $^{f-g}$	5.39 $^{f-g}$	6.66 ^{c}	5.93 ^{ab}	
	4	4.72 ^{h}	5.76 $^{f-g}$	5.83 $^{f-d}$	5.44 ^{cd}	
4	0	6.74 ^{b}	5.93 $^{f-d}$	4.93 $^{f-g}$	5.87 ^{b}	5.91 ^{a}
	2	4.91 ^{fhg}	5.33 $^{f-g}$	6.36 ^{cbd}	5.53 ^{bc}	
	4	4.93 $^{f-g}$	6.28 ^{cbd}	7.75 ^{a}	6.32 ^{a}	
Organic fertilizer		5.34 ^{b}	5.64 ^{ab}	5.80 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	5.05 ^{d}	5.85 ^{ab}	5.40 ^{cd}		
	2	5.45 ^{bcd}	5.21 ^{d}	5.65 ^{bc}		
	4	5.53 ^{bcd}	5.84 ^{b}	6.34 ^{a}		
Seaweed*organic fertilizer	0	5.72 ^{c}	5.38 ^{dc}	5.13 ^{d}	0	5.41 b
	2	5.20 ^{d}	5.27 ^{dc}	5.96 ^{ab}	2	5.48 ^{b}
	4	5.10 ^{d}	6.27 ^{ab}	6.30 ^{a}	4	5.89 ^{a}

Means with the same letters are not significantly different from each other.

Vitamin B1 (µg. L^{-1}):

The results related to vitamin B1 (thiamine) showed a magnitude effect of the studied factors and their interactions on the content of such vitamins in the broccoli plant. The individual dose of humic acid at a concentration (4) ml. L^{-1} created the highest mean average (18.49) µg.ml^{-1} as compared to control.

A similar dosage of seaweed extract granted the maximum average content (18.73) µg.ml^{-1}, surpassing the control (16.87) µg.ml^{-1}. The singular dose of organic manure at both levels (5 and 10) tons. donum^{-1} also importantly elevated vitamin B1 content (17.72 and 17.60) µg.ml^{-1}, respectively, as compared to control (16.51) µg.ml^{-1}.

Regarding the binary effect, the humic acid and seaweed extract were sprayed at a concentration of (4) ml. L^{-1} for each of them drove out to the creation of the excellent content (18.70) µg.ml^{-1} encountered with control (16.19) µg.ml^{-1}. Application of humic at (4) ml. L^{-1} and organic manure at a level of (10) tons. donum^{-1} to the plant significantly improved vitamin B1 content (19.82) µg.ml^{-1} over other different doses.

The combination of the three investigated factors displayed efficiency and that was evident in plants treated with humic acid and seaweed extract at (4) ml.ml^{-1} and organic manures provided at (10) ton.donum^{-1} possessing the largest average value (23.70) µg.ml^{-1} but the least average (13.65) µg.ml^{-1} was found in plants

received manure at (5) ton.donum^{-1} without any treatment of humic or seaweed as clarified in the table (5).

Table 5: Effect of humic acid, seaweed extract, and organic fertilizer on vitamin B1 (µg.ml^{-1}) of broccoli cultivar (Agarssiz)

Humic acid ml. L^{-1}	Seaweed extract ml. L^{-1}	Organic fertilizer tons. donum^{-1}			Humic*seaweed	Humic acid
		0	5	10		
0	0	13.65 ^{n}	15.73 ^{kji}	17.87 $^{g-f}$	15.75 ^{d}	16.30 ^{c}
	2	16.00 ^{lji}	17.50 $^{g-i}$	14.80 ^{lnm}	16.10 ^{d}	
	4	18.20 $^{g-f}$	17.43 ^{ghi}	15.57 ^{lkm}	17.07 ^{c}	
2	0	16.17 l-i	20.77 ^{b}	19.17 ^{ced}	18.70 ^{b}	17.16 ^{b}
	2	14.20 n	14.63 ^{nm}	14.73 ^{lnm}	14.52 ^{e}	
	4	15.63 $^{l-m}$	18.97 $^{c-d}$	20.20 ^{cb}	18.27 ^{b}	
4	0	17.47 $^{g-i}$	14.73 ^{lnm}	15.30 ^{lnm}	15.83 ^{d}	18.49 ^{a}
	2	18.50 ^{gef}	20.73 ^{b}	17.10 ^{ghi}	18.78 ^{b}	
	4	18.80 $^{g-d}$	20.07 ^{cbd}	23.70 ^{a}	20.86 ^{a}	
Organic fertilizer		16.51 ^{b}	17.72 ^{a}	17.60 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	16.19 ^{c}	16.98 $_{b}$	16.08 ^{c}		
	2	18.12 ^{a}	15.33 c	18.03 ^{a}		
	4	18.51 ^{a}	18.26 ^{a}	18.70 ^{a}		
Seaweed*organic fertilizer	0	16.38 ^{de}	16.79 ^{d}	17.44 ^{c}	0	16.87 ^{b}
	2	17.62 ^{c}	16.23 ^{e}	15.54 ^{e}	2	16.47 ^{b}
	4	18.82 ^{b}	17.54 ^{c}	19.82 ^{a}	4	18.73 ^{a}

Means with the same letters are not significantly different from each other.

Total Carotene (Vitamin A) Mg. L^{-1}

Results regarding total carotene in the head displayed that the broccoli crop was positively affected by the application of humic acid, seaweed extract, and organic fertilizer, along with their interactions. The individual concentration of humic at (4) ml.L^{-1} was significant on total carotene (20.37) mg. L^{-1} over control (19.12). A similar significant impact was displayed by seaweed extract at (4) ml.L^{-1}, giving the maximum average mean (20.67) mg. L^{-1} as matched with control (19.26) mg. L^{-1}. In the case of the individual effect of organic manure, plants treated with (10) tons. donum^{-1} of manure owned the best average mean (20.89) mg. L^{-1} relative to control (18.47) mg. L^{-1}.

The data relating to binary effects of factors showed efficacy on total carotene content and humic acid combined with seaweed both at (4) ml.L^{-1} exceeded the total carotene content in head (23.03) mg. L^{-1} was notably better than other dual doses. In the status of humic and organic manure effect, plants dosed with humic acid at a concentration of (0) ml. L^{-1} and organic manure at a level of (10) tons. donum^{-1} contained the highest average value (22.24) mg.L^{-1} in their heads against control plants (15.15) mg.L^{-1}. Furthermore, the bi-lateral interaction of humic acid was given at (4) ml. L^{-1} and organic fertilizer were added at (10) tons. donum^{-1} was responsible for the production of the peak content (23.70) mg. L^{-1} in comparison with control (17.85) mg. L^{-1}. Additionally, the ever-topmost average content (25.69) mg. L^{-1} of total carotene was measured for plants treated with humic acid and seaweed extract each at (4) ml. L^{-1} plus organic fertilizer provided at a rate of (10) ton.donum^{-1} as compared to plants given no dose of all of the studied factors (13.49) mg.L^{-1} as conspicuous in the table (6).

Table 6: Effect of humic acid, seaweed extract, and organic fertilizer on total carotene (vitamin A) µg. L^{-1}of broccoli cultivar (Agarssiz)

Humic acid ml. L^{-1}	Seaweed extract ml. L^{-1}	Organic fertilizer tons. donum^{-1}			Humic*seaweed	Humic acid
		0	5	10		
0	0	13.49 ^{k}	19.74 $^{f-g}$	22.71 ^{bdc}	18.65 ^{cd}	19.12 ^{b}
	2	15.29 ^{k}	19.05 $^{f-g}$	20.69 $^{f-g}$	18.35 ^{d}	
	4	16.67 ^{ij}	21.12 $^{f-g}$	23.32 ^{ab}	20.37 ^{cb}	
2	0	19.57 $^{f-g}$	21.81 $^{f-c}$	19.04 $^{f-g}$	20.14 ^{cd}	19.88 ^{b}
	2	22.06 $^{b-c}$	23.02 ^{abc}	17.61 ^{ijh}	20.90 ^{b}	
	4	16.40 ^{jk}	17.35 ^{ij}	22.09 $^{b-c}$	18.61 ^{d}	
4	0	20.49 $^{f-g}$	18.72 $^{f-g}$	17.73 ^{ijh}	18.98 ^{cd}	20.37 ^{a}
	2	19.66 $^{f-g}$	18.50 $^{i-g}$	19.11 $^{f-g}$	19.09 ^{cd}	
	4	22.62 ^{bdc}	20.78 $^{f-g}$	25.69 ^{a}	23.03 ^{a}	
Organic fertilizer		18.47 ^{b}	20.01 ^{a}	20.89 ^{a}	**Seaweed extract**	
Humic*organic fertilizer	0	15.15 ^{c}	19.97 ^{b}	22.24 ^{a}		
	2	19.34 ^{b}	20.72 ^{ab}	19.58 ^{b}		
	4	20.93 ^{ab}	19.33 ^{b}	20.84 ^{ab}		

Seaweed*organic fertilizer	0	17.85 ^{d}	20.09 ^{cb}	19.83 ^{cb}	0	19.26 ^{b}
	2	19.01 ^{cd}	20.19 ^{b}	19.14 ^{cbd}	2	19.44 ^{b}
	4	18.57 ^{d}	19.75 ^{cb}	23.70 ^{a}	4	20.67 ^{a}

Means with the same letters are not significantly different from each other.

4. DISCUSSION

The study's results revealed that the foliar addition of humic acid, seaweed extract, and soil application of organic fertilizers, either individually or in combination, caused a statistically significant amelioration in the yield qualitative characteristics of broccoli cultivar (Agarssiz) over the control.

The increased yield quality attributed to humic acid may reflect the beneficial role of such bio-stimulants in elevating cell membrane permeability. On the other hand, Humic acid plays a vital role in plant growth by promoting various enzymatic reactions, enhancing cell division and elongation, increasing the levels of plant enzymes, and activating vitamins within cells, which collectively positively affect plant yield and quality (Alfatlawi1 and Alrubaiee, 2020). Furthermore, the potassium and calcium content in the plant can be effectively ameliorated by the addition of humate substances, thereby increasing the fruit's goodness. The same results were found by Al-jaf *et al.* (2018) and Rachid *et al.* (2020), who demonstrated that the application of humic acid on cauliflower led to the production of the maximum floral diameter (cm) and head biochemical content as compared to the control.

The analyzed data with respect to the influence of seaweed extract on head quality showed a prominent effect of seaweed on qualitative traits of broccoli. This may be due to the presence of microelements and plant growth regulators, particularly cytokinins and gibberellins, in seaweed extract. It assists in raising the enzymatic activity of plants, which leads to more metabolic reactions and biosynthesis of carbohydrates, resulting in improved yield quality. Furthermore, the seaweed extract applied to the foliage can have a great effect on root proliferation, which in turn increases the uptake of essential nutrients like N, P, Ca, and S required for the improvement of yield quality (Selvakumari1 and Venkatesan, 2017; Baldaniya *et al*., 2023**)**. The study findings agree with those of Manea & Abbas (2018) on broccoli and Godlewska et al. (2021) on cabbage crop, stating that the foliar spraying of seaweeds significantly improved mineral composition and yield quality traits like head length, head diameter, vitamin C, and carotenoids as compared to the control.

The increase in yield quality attributes due to the application of organic manure could contribute to the beneficial impact of fertilizer on the physical and chemical features of soil by improving soil drainage, aeration, and enhancing soil's ability to retain water. Moreover, organic manure is capable of stimulating the efficacy of premium organic nutrient utilization, which might refer to the quick biodegradation of organic substances, which could have supplied micro and macro nutrients more easily to the plant, thus supporting the nutrients and mineral levels in plant parts. (Mathukiya *et al*., 2023). Our findings are consistent with those of Hammad et al. (2019) and Yoldas et al. (2020) on broccoli, who indicated that soil application of animal manures significantly improved head diameter and length and qualitative traits of broccoli as compared to control.

CONCLUSION

The increased human population and the raised environmental pollution necessitate more use of agricultural land to meet food security. Therefore, more attention has been paid to the utilization of natural sustainable inputs as an alternative to the application of chemical fertilizers that deteriorate the soil architecture and adversely impact environmental health. The study outcomes displayed that the foliar spraying of bio-stimulants and soil addition of organic manure, especially at high doses, significantly increased the qualitative attributes of broccoli yield in comparison with the control. Hence, humic acid, seaweed extract, and organic manure are recommended for the organic production of broccoli crops, with further investigations being implemented on more vegetables in Dohuk province.

Declaration:

I declare that this research manuscript was prepared by me and the work displayed herein is my own, and that this work has not been submitted previously for any other degree or professional qualification. The collaborative contributions have been illustrated clearly and acknowledged.

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Ethical Statement:

Ethical approval was not required for this study, as the reseach did not involve human or animal subjects.

Author Contribution:

The research paper framework was developed by S.F.I. and T.Z.S., from fieldwork through data analysis and manuscript preparation, and the coauthor supervised and contributed to the revision of the manuscript.

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