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EFFECT OF HUMIC ACID LEVELS AND BIOSTIMULANT TREATMENTS ON GROWTH, YIELD, AND VOLATILE OIL PRODUCTION OF CORIANDER (*Coriandrum sativum* L.)

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ABSTRACT

A study was done during two consecutive seasons of 2022/2023 and 2023/2024 to study the effects of humic acid (HU 4, 8, and 12 kg/hectare) as the main plot and BM (Azotobacter chrococum, Azospirulm Brasiliense, and Bacillus polymaxa) and algae extracts (ALG) as the subplot as well as their interactions on plant growth. The design of the experiment was a split plot, including 16 treatments and three replicates. The results showed that the growth parameters, fruit yield measurement, and oil production were noticeably enhanced using humic acid and biostimulants (BM and ALG). In this concern, the high-rise values were obtained by utilizing the high level of HU (12 kg/hectare) with bio-fertilizer (BM + ALG) application compared with control during both seasons. Also, GCMS analysis of the volatile oil revealed that HU and a mixture of bacteria and algae extract had improved the primary volatile oil components of coriander (Linalool - α-Pinene - γ-Terpinene - P-Cymene - Geranial Acetate).

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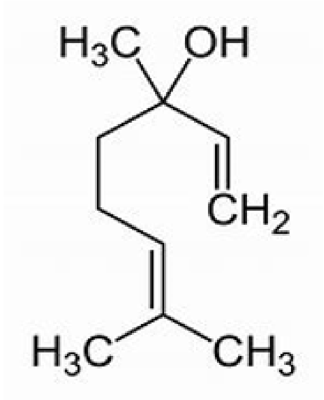
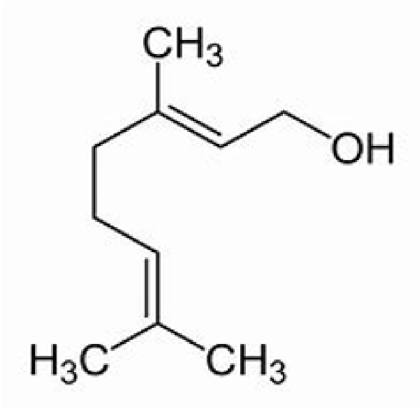
INTRODUCTION

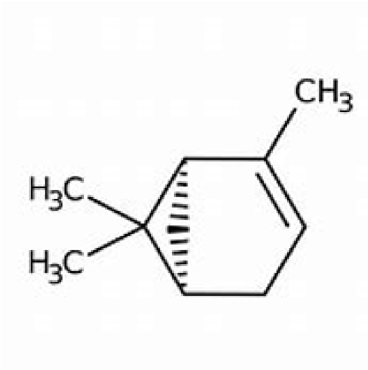
Since they have a wide range of biological and therapeutic activities, lower costs, and higher safety margins than other primary healthcare options, herbal medicines have become highly sought in developing and developed countries. Due to their presence in the plant cell's protoplasm individually or as a pooled form of multiple molecules, these herbal substances are safe and may overcome the resistance produced by pathogenic organisms (Lai and Roy, 2004; Tapsell *et al*., 2006). (Balick and Cox 1996) have pointed out that many significant contemporary medications have been derived from herbs utilized by Indigenous people, even with the introduction of modern or allopathic treatment. Coriandrum sativum L. (coriander) is one of the most severe crops, herbs, spices, medicinal and aromatic plants. It is an annual herbaceous plant belonging to the Apiaceae family. The active component in coriander seeds is an essential oil, widely used as a carminative and antispasmodic in the pharmaceutical industry (Kumar *et al*., 2002). Because of their complex chemical composition, rich flavor, and potent perfume, coriander fruits are essential for processing.



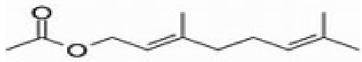
Linalool



Geraniol



α- pinene



Geranyl acetate

Figure (1): The major compounds of coriander essential oil

The primary flavor component in coriander fruits is the essential oil (Figure 1), which has a high concentration of terpinene and other volatile chemicals, including linalool, geraniol, and Diederichsen-pinene (Weiss 2002). Additionally, Singh *et al*. (2006), Matasyoh *et al*. (2009), and Asgarpanah and Kazemivash (2012) reported that the essential oil of coriander has antimicrobial, antifungal, and antioxidant effects. The main nutritional benefits of its fruits and leaves are their high levels of vitamins A and C. 88.01% moisture, 3.29% protein, 6.47% carbohydrates, 1.68% total ash, 0.39% Ca, 0.05% P, 0.02% Fe, 59 mg. /100 grams of vitamins B2, 0.79 mg/100 grams of niacin, 36 mg/100 grams of vitamin C, and 10,458 international units (IU)/100 grams of vitamin A, are all found in its fresh leaves. About 12 grams of carbohydrates, 21 grams of fat, 10 grams of protein, and about 29 grams of crude fiber are included in 100 grams of coriander seeds (Peter, 2004).

(Douda *et al*. 2008) demonstrate that organic manures can be applied as an alternative to mineral fertilizers to enhance soil structure. Furthermore, organic manures are less expensive than chemical fertilizers and are used from locally produced goods and living stack wastes (Solomon, 2012). According to (Judais and Rinaldi 2001) and (Taiwo *et al*. 2002), the provision of organic manures improved and maintained the manual value while enhancing the soil's biological activity and significantly impacting the quality. Additionally, a lot of countries have changed to organic farming. In Egypt, organic agriculture is vital in preserving public health and preventing sickness. Moreover, organic agriculture was adopted globally to replace chemical, pesticide, and fertilizer use with organic farming practices. (Elham and Rania, 2015) on Hibiscus sabdariffa, and (Rania and Abd El-Azim, 2016) on Plantago plants. Plant-promoting hormones, such as GA and IAA, macronutrients, beneficial microbes, and vital micronutrients, are all present in organic manures. (Natarajan, 2007, Sreenivasa *et al*., 2010 and Shawkat & Ibrahim 2023). According to (Chen *et al*., 2004), Humic acids (HU) are the most active compounds in soil and organic matter compost. They work on mechanisms that encourage plant development and ultimately increase yield. Specifically, the 50-300 mg/l range has been discovered to include ideal concentrations that influence and stimulate plant growth. However, lower concentrations also have sound effects (Chen *et al*., 2004). Plants can benefit from humic acid, a naturally occurring chemical, in several physiological and biological ways. It stimulates the production of natural oxides, activates and speeds up seed germination, and promotes the development of root principles. Furthermore, it is thought to be a naturally occurring chelating agent that helps the soil's constituent elements—Fe, Z, Cu, P, Ca, Mg, and Mn—to transform into a soft, easily absorbed form. Furthermore, it stimulates the activity of plant-derived enzymes and energy molecules, triggering the release of internal cytokinin and promoting cell division and elongation (Abdul Hafiz, 2012). The cementing plant growth due to the use of an organic system was detected by many researchers, such as, (Hamza *et al*., 2021; Rania and Salama, 2021; Rasouli *et al*., 2022) on coriander (Gohari *et al*., 2017; El Gohary *et al*., 2023; Sayarer *et al*., 2023) on basil, (Mahmoud *et al*., 2017; El-Banna and Fouda, 2018; Hassan, 2019; Omer *et al*., 2020; Hassan *et al*., 2024) on caraway, (Khoshghalba *et al*., 2017; Hassan and Fahmy, 2020 and Ahmed *et al*., 2022) on chamomile plant, (Aly *et al*., 2022) on anise, (Yadegari, 2022) on satureja plants, (Hamid, 2023). on (Mentha piperita L., (Hanfy *et al*., 2019), on oregano (Origanum syriacum L.), (Rania *et al*., 2022) on ruta (Ruta graveolens L). (Abd-El Hameed, 2023) on sweet marjoram (Marjorana hortensis L.) and (Khosravi *et al*., 2023) on common sage.

Using a biofertilization system, which contains many bacterial strains, led to the economical use of mineral fertilizers and, thus, obtaining high-quality agricultural products. (Mahfouz and Sharaf-Eldin 2007) Another strategy for achieving potential agriculture is the utilization of biofertilizers, which are beneficial microorganisms that play a crucial role in meeting the nutrient requirements of plants. (Bhardwaj *et al*., 2014 and Raghad *et al* 2021). The predominant type of free-living, nonsymbiotic, and heterotrophic N-fixing bacteria in alkaline or neutral soil types (Wani *et al*., 2016). Moreover, bio-fertilizers are administered to the soil, fruit, or root and promote the establishment of microflora, enhanced nutrient availability, and nitrogen fixation. It increased nutrient availability by using nitrogen-fixing biofertilization and organic systems (Babaleshwar *et al*., 2017; Afnan *et al*., 2021). The improvement in growth parameters due to the inoculation with N-fixing bacteria was reported by (Rahimi *et al*., 2009; Sahu *et al*., 2014 Hegazi, 2015, Sahu and Sahu 2018, Swain, 2020, Ali *et al*., 2023) on coriander, (ElHoussini, 2009 and Abd El-Rahman *et al*., 2023) on borage, (Hasan and Rabie, 2019) on basil. (Ibrahim, 2014) on Alexandrian senna (Cassia acutifolia) plants (Kusuma *et al*., 2019) on fennel (Mazrou *et al*., 2022) on Majorana hortensis L. Seed yield was augmented due to the inoculation of N-fixing bacteria indicated on coriander (Rahimi, 2009, Sahu *et al*., 2014, Hegazi, 2015, Sahu and Sahu 2018, Swain, 2020 and Chaithanya *et al*., 2023), on borage (Hendawy and El-Gengaihi, 2010 and ElHoussini, 2009, Abd El-Rahman *et al*., 2023), on black cumin (Safwat and Badran, 2002 and Valadabadi and Farahani, 2011). on Alexandrian senna (Ibrahim, 2014), on fennel (Kusuma *et al*., 2019), An augment in coriander essential oil content (Rahimi, 2009, Darzi, 2013, Hegazi, 2015, Sharma *et al*., 2023), on Anethum graveolens (Darzi, *et al*., 2012 and Hegazi, 2015) and on Majorana hortensis L. (Mazrou, *et al*., 2022).

Utilizing efficient biostimulants is also necessary. Spirulina platensis algae extract improves and controls the physiological functions of the crop. Through a variety of mechanisms, it affects plant physiology to enhance nutrient uptake, yields, quality, and resistance to abiotic challenges in crops, as noticed by Abd El-Aleem *et al*. (2017), Yakhin *et al*. (2017), Rouphael and Colla (2018) and Ronga *et al*. (2019). Natural growth regulators found in algae extracts actually postpone the plant's entry into the aging stage. They also stop harvesting, flowering, and leaf fall. Because of the way they affect protein, they also stop yellowing. They prevent the breakdown of chlorophyll and conserve it. They promote root growth and induce cell division. It is among the most significant scientific reasons for how algae extracts affect the productivity and development of numerous commercial plants (Khater, 2016).

Moreover, algae contain natural phenols like tannins that function similarly to natural growth hormones. They also help plants produce more lignin, which makes them more disease-tolerant. Similarly, they facilitate faster nutrient absorption by including alginic acid, a naturally occurring chelating agent that chelates nutrients with a soil solution. They additionally include many vitamin types, such as C, B1, B2, and B12. Because algae contain free amino acids, which promote balanced, productive development and enhance the plant's response to fertilization, they function as both natural antibiotics and growth regulators within the plant (Marrez *et al*., 2014). Algae extracts can be used directly as organic fertilizers by adding them to the soil or foliar treatment to enhance and improve productivity, quality, and metabolites. (Tursun, 2022). The increments in growth aspects, seed yield, and oil production due to using biostimulants have been studied by (Aishwath *et al*. 2012, Manhart and Delibaltova, 2022, Tursun, 2022) on coriander (El Laban *et al*. 2017, Wafaa *et al*., 2017, Hassan, *et al*., 2022) on fennel, (Atteya and Amer, 2018 and Mahmoud *et al*., 2021) on roselle, (Nofal *et al*. 2015) on golden marigold, (Ramya *et al*. 2011) on guar and (Mohammad 2020) on Nigella sativa plants. Thus, this work aimed to assess how humic acid levels and various biostimulant treatments (atmospheric nitrogen-fixing bacteria and algal extract mixture) affected the development, yield, and volatile oil production of coriander plants.

MATERIALS AND METHODS

This experiment was conducted at the Farm of Fac. Agric., Al-Azhar University, Assiut, Egypt, throughout the two consecutive seasons of 2022/2023 and 2023/2024 to enhance the growth and production of the coriander plant. The experiment included two factors: humic acid (HU 1,2 and 3 = 4,8 and 12 kg/hectare) as the main plot and BM (Azotobacter chromium, Azospirulm Brasiliense, and Bacillus polymath) and algae extracts (ALG) as the subplot and their interactions.

Design of Experiment

A split plot with three replicates was utilized as the experimental design of this work, using a randomized complete blocks design (RCBD). Humic acid (four levels) occupied the main plot, and BM (Azotobacter chrococum, Azospirulm bracilianse, and Bacillus polymaxa) and algae extracts (ALG) (four treatments) as the sub-plots. The interactions between the main factors were 16 treatments.

The treatments were conducted as follows:

1	Control	9	HU 2+ Control
2	BM	10	HU 2+ BM
3	ALG	11	HU 2 + ALG
4	BM+ALG	12	HU 2 + BM+ALG
5	HU 1+ Control	13	HU 3 + Control
6	HU 1+ BM	14	HU 3 + BM
7	HU 1+ ALG	15	HU 3 + ALG
8	HU 1+ BM+ALG	16	HU 3 + BM+ALG

Material and Culture of Plants

Coriander seeds were obtained from the Agric. Res. Centre, of Med. and Aroma. Plants Dept. in Dokky, Giza, Egypt. On November 5th, during the two seasons, these fruits were immediately sown in the plot 3 x 3 meters, making up the experimental unit area. Each experimental unit had five rows, each 3 meters long, 60 cm separated from the ridges, and 30 cm apart in the hills. Each hill received about 5-7 fruits, subsequently thinned to 2 plants/ hill. As a result, the experimental unit included 72 plants. Some of the chemical and physical characteristics of the soil utilized for current work are tabulated in Table (1), as reported by Chapman and Pratt (1978).

Table (1): Some of the soil's chemical and physical characteristics that were employed in this study

Characteristics		Value	
		2022/2023	2023/2024
Particle size distribution	sand (%)	19.98	19.11
	silt (%)	57.44	58.14
	clay (%)	22.58	22.75
Texture grade		silty loam	silty loam
Soil water suspension pH (1:2.5) (w/v)		7.7	7.4
ECe ($dS \cdot m^{-1}$) soil paste		2.19	2.11
Organic matter (%)		0.55	0.59
$CaCO_3$ (%)		2.61	2.52
HCO^{3-} (cmol kg^{-1} of soil)		3.1	3.3
Cl–		2.3	2.2
SO42–		6.7	6.6
Ca2+		3.7	3.5
Mg2+		2.2	2.4
K+		3.48	3.41
Na+		21.82	19.33

Rates and method of adding humic and microbial inoculants

The humic acid levels used in this study are 4, 8, and 12 kg/hectare /ha. They were added with irrigation water to plants at with sowing after 35- and 65-days following cultivation.

The Microbiol. Dept. of the Water, Soils and Environment Res. Instit. (ARC), Giza, Egypt, graciously donated the bacteria mixture (Azotobacter chromium, Azospirulm Brasiliense, and Bacillus polymath) and algae extracts (ALG) used in the manuscript. The bacteria mixture was added by injecting it under the plants 10 and 40 days after planting, while algae extracts were applied as foliar applications two times 50 and 75 days from planting.

Sampling and Data Collection

One hundred days after coriander fruits were planted, three randomly chosen plants per experimental plot were studied for the following characteristics: plant height (cm), branch number per plant, and weight of fresh and dry herb, g/plant. The following information was noted during harvesting in both seasons during the third week of April: The yield of volatile oil (ml)/plant was estimated by reducing the percentage of volatile oil by the plant's fruit yield (g). The volatile oil yield (liters/ha) was then calculated based on the number of umbels/plants, fruit productivity (grams/plant), (kg/ha), and percentage of volatile oil in the fruits.

Volatile oil isolate

During both experimental seasons, coriander fruits were gathered from each treatment and weighed to extract volatile oil. Next, 100 g of each repeat of every transaction was subjected to 3 hours of hydro distillation (H.D.) utilizing a Clevenger-type apparatus (1928). Relative percent (v/w) was used to compute the V.O. content. Additionally, dry weight was used to calculate the total V.O., expressed as ml/100 plants. The extracted V.O.s were collected from coriander fruits during the two successive seasons of any treatment and dried Anhydrous Na2SO4 for Chemical Determination voters.

According to Mead *et al*. (1993), all the data collected for this study were organized, documented, and statistically evaluated, as presented in MSTAT (1986) utilizing the L.S.D. test at 5% to determine the differences between all treatments.

RESULTS AND DISCUSSION

Growth parameters

The presented data in Table (2) reveal that utilizing humic acids (HU) at any concentration significantly increased plant height (cm), branch number, and fresh and dry weights of herb (g/plant) of coriander plants during both seasons. Plants grown in organic manure (humic acids) at the high level (12 kg/hectare) registered high-rise growth parameter values, which increased plant height by 29.0 and by 25.9 %, augmented the number of branches by 167.4 and by 143.4 %, elevated herb fresh weight by 26.0 and 25.6 % and increased herb dry weight by 37.0 and by 33.2 % over the control, during the two experimental seasons, respectively. Additionally, the ability of organic fertilization to increase the growth aspects found in this study was revealed by Hamza *et al*., 2021, Rania and Salama, 2021 and Rasouli *et al*., 2022) on coriander (Rania *et al*., 2022) on ruta (Ruta graveolens L.) and (Abd-El Hameed, 2023) on sweet marjoram.

The information provided in Table (2) on the biostimulant treatments showed that over the two growth seasons, inoculation with BM and ALG resulted in positive responses regarding plant growth traits.

Table (2): Effect of humic acid and some biostimulant on growth measurements of coriander (*Coriandrum sativum* L.) plants during 2022/2023 and 2023/2024 growing season.

Humic acid		Growth parameters							
		Plant height (cm)		Branch number / plant		herb fresh weight /plant (g)		herb dry weight /plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Effect of Humic acid rates									
Control		58.00	62.17	8.625	10.63	81.92	85.00	18.92	20.47
HU 1		67.75	71.58	14.50	16.63	90.33	93.25	21.17	23.01
HU 2		71.25	75.00	19.17	21.83	98.42	102.5	22.67	23.68
HU 3		74.75	78.25	23.00	25.83	103.2	106.8	25.88	27.30
L.S.D. at 5 %		A: 3.3	A: 2.3	A:1.7	A:2.4	A:1.9	A:3.1	A: 2.0	A:2.1
Effect of biostimulants									
Control		62.08	65.92	13.54	15.46	88.17	91.0	20.29	21.15
BM		68.83	72.83	16.88	19.46	94.67	98.3	22.71	23.88
ALG		67.25	71.17	15.96	18.21	92.92	96.5	21.63	23.42
BM+ALG		73.58	77.08	18.92	21.79	98.08	101.8	24.00	26.00
L.S.D. at 5 %		B: 4.4	B: 3.6	B:1.8	B:2.2	B:2.7	B:2.5	B:1.1	B:1.6
Effect of combination between Humic acid and biostimulants									
Control	Control	53.33	57.33	7.167	8.667	79.00	81.33	17.3	17.87
	BM	59.67	64.00	8.500	10.83	82.67	86.00	19.2	21.00
	ALG	58.33	62.67	7.833	10.33	80.33	84.00	18.2	19.83
	BM+ALG	60.67	64.67	11.00	12.67	85.67	88.67	21.0	23.17
HU 1	Control	62.00	65.00	12.00	13.67	88.00	90.33	19.7	20.53
	BM	67.67	72.67	15.00	17.33	90.67	94.00	21.8	23.83
	ALG	66.67	71.67	14.00	16.00	89.67	92.67	20.7	22.83
	BM+ALG	74.67	77.00	17.00	19.50	93.00	96.00	22.5	24.83
HU 2	Control	66.00	69.67	15.67	18.50	92.33	95.67	20.3	22.67
	BM	72.00	75.33	20.00	22.67	99.33	103.3	23.3	22.37
	ALG	70.00	73.00	19.00	20.83	97.33	101.7	22.3	24.00
	BM+ALG	77.00	82.00	22.00	25.33	104.7	109.3	24.7	25.67
HU 3	Control	67.00	71.67	19.33	21.00	93.33	96.67	23.8	23.53
	BM	76.00	79.33	24.00	27.00	106.0	110.0	26.5	28.33
	ALG	74.00	77.33	23.00	25.67	104.3	107.7	25.3	27.00
	BM+ALG	82.00	84.67	25.67	29.67	109.0	113.0	27.8	30.33
L.S.D. at 5 %		AB:8.8	AB:7.2	AB:3.7	AB:4.4	AB:5.4	AB:5.1	AB:2.2	AB:3.2

Hu 1=4, Hu 2= 8 and Hu 3=12 kg/hectare.; BM= *Azotobacter chrococum*, *Azospirulm bracilianse* and *Bacillus polymaxa* and ALG = algae extract;

The utilized interacted treatments resulted in higher values of plant height (cm), branch number, and fresh and dry weights (g/plant) than those recorded by single ones throughout the two subsequent seasons. In general, the injection with the BM + ALG proved more effective in enhancing vegetative growth parameters than those noticed by control and others during both seasons. The percentage of plant height, branch number, and herb fresh and dry weight increased from 18.7 and 17.0, 40.0 and 40.6, 11.2 and 11.9, and 18.2 and 22.6% over un-inoculated ones in both seasons, respectively. According to the studies collected also showed that bio-stimulants increased growth parameters output (Sahu *et al*., 2014; Hegazi, 2015; Sahu and Sahu, 2018; Swain, 2020; Tursun, 2022; Ali *et al*., 2023) on coriander (ElHoussini, 2009 and Abd El-Rahman *et al*., 2023) on borage, (Ibrahim 2014) on Alexandrian senna (Cassia acutifolia), (Nofal *et al*. 2015) on Calendula officinalis, (El Laban *et al*., 2017, Wafaa *et al*., 2017, Hassan *et al*., 2022) on fennel and (Mazro *et al*., 2022) on majorana hortensis L.).

As for the interaction impact, it was a significant influence on the vegetative growth parameters in the two growing seasons (Table 2). It was shown that, compared to control plants, treating the plants with the most combined treatments resulted in a considerable rise in these parameters for both seasons. Furthermore, in contrast to other combination treatments, the most successful method for increasing growth traits (plant height, branch number, and fresh and dry herb weights) was inoculating plants grown in organic conditions (humic acids) at a high level (12 kg/hectare). This was true during the two seasons.

Yield components

Results in Table (3) postulated that umbel number/plant, seed yield/ plant (g), and seed yield/ Hectare (ton) positively responded to supplement the plants with humic acids during the two successive seasons. In contrast to the control, however, adding such manure at all levels during the two seasons resulted in a notable increase in yield components. Therefore, the maximum value of umbel number/plant, seed yield/ plant (g), and seed yield/ Hectare (ton) were detected from plants grown in organic conditions (humic acids) at the high level (12 kg/hectare) which improved umbels number/plant by 50.3 and 54.0 %, augmented seed yield/ plant (g) by 58.2 and 60.2 % and elevated seed yield/ Hectare (ton) by 58.2 and 60.0% over control, in both seasons, respectively. The critical role of organic manures in elevating seed yield has been explored by (Omer *et al*., 2020, Rania and Salama, 2021 Rasouli *et al*., 2022, and Hassan *et al*., 2024) on Coriander (Carum carvi L.), (Abd-El Hameed, 2023) on sweet marjoram (Marjorana hortensis L.) and (Khosravi *et al*., 2023) on sage.

The findings shown in Table (3) demonstrated that, throughout the 2022/2023 and 2023/2024 seasons, the use of bio-stimulants was favorably associated with umbels number/plant, seed yield/plant (g), and /hectare (ton). The presence of bio-stimulants at all levels, in both seasons, led to a significant increase in yield components, except for the (ALG) treatment, in both seasons, regarding umbels number/plant relative to the check treatment. In connection, (BM+ALG) gave the maximum values in these treatments, ranged 27.6 and 24.8, 27.5, 28.3, 27.5, and 28.1 % over control in both seasons, respectively. The advantageous function of bio-stimulants in enhancing alkaloids content was also described by (Rahimi *et al*., 2009, Sahu *et al*., 2014, Hegazi, 2015, Sahu and Sahu 2018, Swain 2020 and Chaithanya *et al*., 2023 Ali *et al*., 2023) on coriander, (ElHoussini 2009, Hendawy and El- Gengaihi 2010, Abd El-Rahman *et al*., 2023), on borage, (Kusuma *et al*., 2019) on fennel, Mohammad (2020) on Nigella sativa plants and (Mahmoud *et al*. 2021) on roselle.

Table (3): Effect of humic acid and biostimulant on yield measurements of coriander (*Coriandrum sativum* L.) plants during 2022/2023 and 2023/2024 growing season

Humic acid		Yield components					
		umbels number/ plant		Fruit yield/ plant (g)		Fruit yield/ Hectare (ton)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Effect of Humic acid rats							
Control		17.26	18.67	16.50	17.64	1320	1411
HU 1		20.51	22.75	20.21	22.18	1616	1774
HU 2		24.43	26.92	20.29	22.35	1623	1788
HU 3		26.01	28.75	26.13	28.23	2090	2258
L.S.D. at 5 %		A:2.4	A: 2.0	A:1.27	A: 1.53	A:101.6	A:122.3
Effect of biostimulants							
Control		19.58	21.83	18.21	19.83	1456.7 a	1586.7 a
BM		22.42	24.67	21.46	23.17	1716.7 b	1853.3 b
ALG		21.17	23.42	20.25	22.00	1620.0 b	1760.0 b
BM+ALG		25.03	27.17	23.21	25.40	1856.7 c	2032.0 c
L.S.D. at 5 %		B: 2.4	B: 2.5	B:1.64	B: 2.00	B:131.3	B: 159.9
Effect of combination between Humic acid and biostimulants							
Control	Control	15.33	17.00	14.17	15.17	1133	1213
	BM	17.67	19.00	17.00	18.00	1360	1440
	ALG	17.00	18.00	16.00	17.00	1280	1360
	BM+ALG	19.03	20.67	18.83	20.40	1506	1632
HU 1	Control	18.33	20.67	17.33	19.00	1386	1520
	BM	21.00	23.67	21.33	23.50	1706	1880
	ALG	20.00	22.00	20.00	22.50	1600	1800
	BM+ALG	22.70	24.67	22.17	23.73	1773	1898
HU 2	Control	21.67	24.00	18.67	20.67	1493	1653
	BM	25.00	27.33	20.50	22.17	1640	1773
	ALG	23.00	26.00	19.67	21.17	1573	1693
	BM+ALG	28.03	30.33	22.33	25.40	1786	2032
HU 3	Control	23.00	25.67	22.67	24.50	1813	1960
	BM	26.00	28.67	27.00	29.00	2160	2320
	ALG	24.67	27.67	25.33	27.33	2026	2186
	BM+ALG	30.37	33.00	29.50	32.07	2360	2565
L.S.D. at 5 %		AB:5.9	AB:4.9	AB: 3.28	AB: 4.00	AB:262.6	AB:319.8

Hu 1=4, Hu 2= 8 and Hu 3=12 kg/hectare.; BM= *Azotobacter chrococum, Azospirulm bracilianse* and *Bacillus polymaxa* and ALG = algae extract;

During the 2022/2023 and 2023/2024 seasons, the coriander plants' umbel counts per plant, fruit yield per plant (g), and per hectare (ton) were significantly impacted by the interaction treatments between the two components under investigation. It was evident from the data that applying the most significant number of combination treatments during both seasons considerably raised this parameter compared to the untreated ones. In contrast to those obtained by other combination treatments, it appears that the most successful treatments in mounting yield parameters were those that included high levels of humic acids (12 kg/hectare) and BM+ALG injection, followed by high levels of humic acids plus BM during the two growing seasons (Table 3).

Volatile oil Yield

Humic acids (HU) applied to coriander plants throughout the two experimental seasons had a favorable effect on volatile oil % as well as yield of volatile oil /plant (ml) and /hectare (l). Such aspects were significantly raised due to the use of humic acid (HU) at all levels, except for the low one in the second season concerning volatile oil % also volatile oil/ plant(ml) and / hectare (l) in the 1st season, in relative to unfertilized plants.

Table (4): Effect of humic acid and biostimulant on volatile oil measurements of coriander (*Coriandrum sativum* L.) plants during 2022/2023 and 2023/2024 growing season

Organic manure		Oil Yield					
		Volatile oil %		Yield of volatile oil/ plant(ml)		Yield of volatile oil/ Hectare (L)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Effect of Humic acid rats							
Control		0.202	0.234	0.045	0.042	3.567	3.386
HU 1		0.277	0.274	0.064	0.062	5.140	4.992
HU 2		0.346	0.324	0.073	0.074	5.820	5.937
HU 3		0.424	0.409	0.115	0.117	9.227	9.346
L.S.D. at 5 %		A:0.071	A:0.048	A:0.020	A:0.013	A:1.62	A:1.07
Effect of biostimulants							
Control		0.254	0.254	0.060	0.055	4.840	4.373
BM		0.316	0.325	0.076	0.078	6.093	6.210
ALG		0.313	0.299	0.072	0.068	5.733	5.435
BM+ALG		0.366	0.363	0.089	0.096	7.087	7.644
L.S.D. at 5 %		B:0.048	B:0.036	B:0.010	B:0.011	B:0.83	B: 0.85
Effect of combination between Humic acid and biostimulants							
Control	Control	0.130	0.176	0.033	0.028	2.667	2.214
	BM	0.223	0.253	0.047	0.046	3.760	3.651
	ALG	0.215	0.223	0.044	0.038	3.520	3.038
	BM+ALG	0.240	0.284	0.054	0.058	4.320	4.643
HU 1	Control	0.242	0.197	0.053	0.040	4.213	3.213
	BM	0.280	0.297	0.068	0.070	5.440	5.600
	ALG	0.275	0.277	0.065	0.062	5.227	4.987
	BM+ALG	0.310	0.324	0.071	0.077	5.680	6.169
HU 2	Control	0.300	0.280	0.062	0.061	4.960	4.909
	BM	0.320	0.333	0.072	0.074	5.733	5.915
	ALG	0.350	0.310	0.069	0.066	5.493	5.253
	BM+ALG	0.415	0.374	0.089	0.096	7.093	7.672
HU 3	Control	0.343	0.363	0.094	0.089	7.520	7.156
	BM	0.440	0.417	0.118	0.121	9.440	9.672
	ALG	0.413	0.387	0.109	0.106	8.693	8.463
	BM+ALG	0.498	0.468	0.141	0.151	11.25	12.09
L.S.D. at 5 %		AB:0.097	AB:0.072	AB: 0.02	AB:0.021	AB:1.66	AB:1.70

Hu 1=4, Hu 2= 8 and Hu 3=12 kg/hectare.; BM= *Azotobacter chrococum, Azospirulm bracilianse* and *Bacillus polymaxa* and ALG = algae extract;

Plants grown in organic manure (humic acids) at the high level registered the maximum values of the three examined parameters, which increased volatile oil %

by 109.7 And by 74.7%, volatile oil/ plant (ml) by 157.8 And by 176.1 % and volatile oil/ hectare (L) 158.8 and by 175.9 % over the check treatment, during both seasons, respectively, as mentioned in Table (4).

The role of organic manure in increasing oil yield parameters detected in this study was also insured by Hamza *et al*., 2021 Rania and Salama, 2021 and Rasouli *et al*., 2022) on coriander (Gohari, *et al*., 2017, El Gohary *et al*., 2023 and Sayarer, *et al*., 2023) on basil, (Mahmoud, *et al*., 2017, El-Banna, and Fouda, 2018 Hassan, 2019, Omer *et al*., 2020 and Hassan *et al*., 2024) on caraway (Carum carvi L.), (Ahmed *et al*., 2022) on chamomile, (Aly *et al*., 2022) on anise and (Hamid, 2023) on (Mentha piperita L.).

Regarding bio-stimulant treatments, the given data in Table (4) showed that oil yield parameters (volatile oil percentage/plant (ml) and / hectare (L)) of coriander plants positively responded to adding bio-stimulant during both seasons and treating the plants with bio-stimulant significantly increased volatile oil % and volatile oil yield/plant (ml) and / hectare (L) in both seasons compared to untreated plants. Numerically, treating plants with combined treatment (BM+ALG) elevated volatile oil % by 44.2 and 42.7 %, augmented volatile oil/ plant (ml) by 46.4 and 74.6 %, and increased volatile oil/ hectare (L) by 46.4 and by 74.8 %over untreated plants, in 1st and 2nd seasons, respectively.

The primitive impact of biostimulant treatments on oil yield aspects revealed in this research was also mentioned on coriander (*Coriandrum sativum* L.) (Rahimi, 2009; Darzi, 2013; Hegazi, 2015; Ali *et al*., 2023 and Sharma *et al*., 2023), on Anethum graveolens, (Darzi *et al*., 2012 and Hegazi, 2015) and on Majorana hortensis L. (Mazrou, *et al*., 2022). Concerning the interaction effect between the two main factors, the results indicated positive differences in the volatile oil measurements of coriander plants during the two agricultural seasons (Table 4). It was noted that giving the plants the combined treatment led to a significant effect in these measurements, in contrast to the untreated plants during the two agricultural seasons. Moreover, plants grown in organic conditions (humic acids) at a high level (12 kg/hectare) and treated with the combined biostimulant (BM+ALG) was the most effective treatment in raising the oil yield parameters, primarily, in comparison with those obtained by other combinations, during both seasons.

Components of volatile oil

The GC/MS chromatographic analysis presented in Table (5) demonstrated that the coriander volatile oil extracted from the fruits in this experiment consists of (17) compounds. It became clear when comparing the values of the chemical compounds of the oil. We notice that the volatile oil compounds Linalool - α-Pinene - γ-Terpinene - Geranial Acetate and P-Cymene are the highest in percentage compared to the other compounds. The highest average for linalool (67.81) was when adding a high percentage of humic acid (12 kg/ha) with algae extract alone. While the highest percentages of alpha-pinene (6.33) were recorded when a high percentage of humic acid (12 kg/ha) was added to the bacterial mixture, the high-rise percentages of Geranyl acetate (7.32) were noticed when a high percentage of humic acid was added. Acid 12 kg/ha with algae extract alone as well. This explains that utilizing HU and algae extract with a mixture of bacteria that fix atmospheric nitrogen had a noticeable effect on the volatile content of coriander volatile oil from the main compounds and the other compounds. This is consistent with the findings of Mahfouz *et al*. (2007) and Maada *et al*. (2007), who discovered an enhancement in the proportion of oil and the fertilization types and their effects on giving all the plant nutrients. These findings follow the observations of Khalid and Shafei (2005) on dill, Osman (2009) on Foeniculum vulgare, Ateia *et al*. (2009) on Thymus vulgaris, and Biasi *et al*. (2009) on Ocimum basilicum. According to Mahfouz and Sharaf Eldin (2007), the compounds were affected by nitrogen-fixing bacteria because of enhanced nitrogen intake and improved growth. Numerous researches have demonstrated that essential oil components increased when organic manures and bio-fertilizers interacted (Harshavardhan *et al*., 2007; Padmapriya and Chezhyian, 2009).

Table (5): Effect of humic acid and biostimulant on volatile oil components of coriander (*Coriandrum sativum* L.) fruit as the average of second growing seasons

No	Compound	R T	Treatments			
			control	HU 3 + BM	HU 3 +ALG	HU 3+BM+MF
1	α-Pinene	7.43	3.60	6.33	4.16	6.22
2	β-Pinene	6. 375	0.41	0.60	0.61	0.64
3	p-Cymene	8.699	4.78	4.57	4.32	4.33
4	D-Limonene	8. 673	3.76	4.29	0.91	1.02
5	γ-Terpinene	9.604	7.63	9.69	11.29	11.39
6	Linalool	10.837	54.39	59.18	67.81	66.40
7	(+)-2-Bornanone	12.084	1.34	0.96	0.65	1.17
8	Terpinen-4-ol	13.984	0.52	--	--	0.50
9	Dill ether	12.221	0.48	--	--	--
10	Decanal	13.688	0.56	--	0.82	0.55
11	trans-Dihydrocarvone	13.747	0.52	--	--	--
12	(-)-Carvone	15.838	9.15	3.25		0.53
13	Geraniol	14.069	0.89	0.73	0.85	0.81
14	Piperitone	15.138	1.53	--	--	--
15	Geranyl acetate	18.465	5.29	5.55	7.32	5.94
16	2-Dodecenal	21.549	--	--	0.70	--
17	Apiol	23.43	5.18	4.85	0.61	--
N.of identified elements			16	11	12	12
Total percentages of identified elements			100	100	100	99.52

Hu 1=4, Hu 2= 8 and Hu 3=12 kg/hectare.; BM= *Azotobacter chrococum*, *Azospirulm bracilianse* and *Bacillus polymaxa* and ALG = algae extract;

CONCLUSIONS

One of the most important results of this study is that the different levels of humic acid used led to an improvement in the productivity of the coriander plant. Growth, seed yield, and oil yield of the coriander plants significantly improved with the mixture of bacteria that fix atmospheric nitrogen and in the presence of algae extract as well (Azotobacter chrococum, Azospirulm bracilianse and Bacillus polymaxa and algae extract) in both study seasons compared to control. Humic acid and the bio-stimulant interaction significantly affected growth, yield, and oil index. The best treatment was humic acid at a high level (12 kg/ha) combined with bio-stimulants (BM+ALG).

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CONFLICT OF INTEREST

The authors state that there are no conflicts of interest with the publication of this work.

التأثير المتكامل لحامض الهيومك والمنشطات الحيوية لتحسين إنتاجية نباتات الكزبرة

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الخلاصة

تم إجراء هذه التجربة في المزرعة البحثية بكلية الزراعة جامعة الأزهر، أسيوط، مصر، خلال الموسمين المتتاليين 2023/2022 و 2024/2023 وذلك لدراسة المعاملة بمستويات مختلفة من حامض الهيوميك (0، 4، 8 و 12 كجم/ هكتار) ، و التلقيح ببعض المنشطات الحيوية (خليط البكتريا "ازوتوباكتر كوركوكيم ، ازوسبيرليم براسيلنس و باسيلس يوليميكسا"+ مستخلص الطحالب) علي خصائص النمو الخضري (ارتفاع النبات، عدد الأفرع، وزن العشب الطازج والجاف / نبات) ، صفات المحصول والانتاجية (عدد النورات / نبات، إنتاجية الثمار/ نبات (جم) وإنتاجية الثمار/هكتار (كجم) ومحتوي الزيت العطري وبعض مكوناته لنباتات الكزبرة. أظهرت النتائج المتحصل عليها أن خصائص النمو وإنتاجية الثمار وإنتاج الزيت قد تحسنت بشكل ملحوظ نتيجة اضافة حامض الهيوميك إلى جانب استخدام المنشطات الحيوية (خليط البكتريا + مستخلص الطحالب)، حيث تم الحصول على أفضل النتائج في هذا الصدد باستخدام اعلي مستوى من حامض الهيوميك (12 كجم/هكتار) مع إضافة التسميد الحيوي (خليط البكتريا + مستخلص الطحالب) مقارنة بالنباتات الغير معاملة خلال كلا موسمي التجربة. وكذلك أشارتحليل GCMS للمركبات الطيارة للزيت إلى أن حامض الهيوميك وخليط البكتيريا مع مستخلص الطحالب قد حسن مكونات الزيت الطيار الرئيسي للكزبرة (لينالول γ–تربينين – ألفا – بينين – بي – سيمين – جيرانيال أسيتات).

الكلمات المفتاحية: الكزبرة، حامض الهيوميك، خليط بكتيريا ومستخلص الطحالب.

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