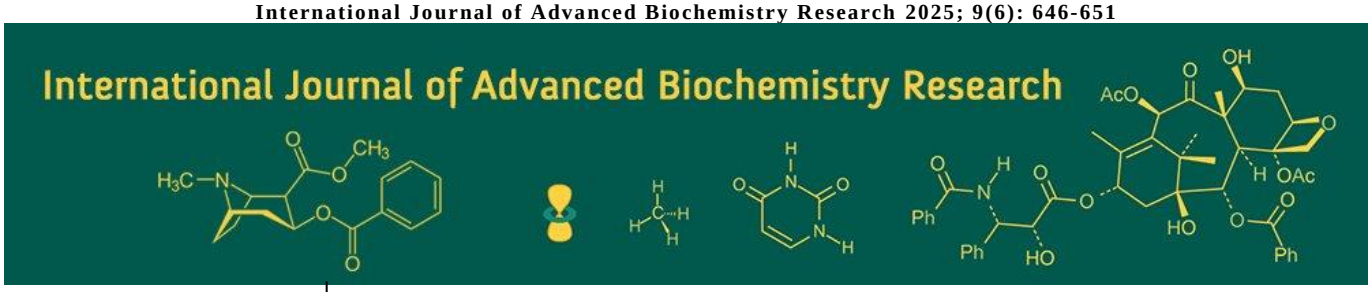

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Response of bioactive compounds in coriander (*Coriandrum sativum L.*) to foliar application of *Moringa* and barley seed extracts and biofertilization

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Abstract
Modern agricultural practices emphasize enhancing plant productivity and development through the use of organic extracts and bio-fertilizers, which serve as natural reservoirs of essential nutrients and are considered effective and readily absorbed by plants. A field experiment was conducted during the autumn season of 2024-2025 to enhance the bioactive compounds in coriander (*Coriandrum sativum L.*) using organic extracts and microbial inoculants, aiming to reduce the negative impact of chemical fertilizers. The experiment was arranged using a split-plot design within a randomized complete block design (R.C.B.D) with two factors. The first factor was microbial inoculation, consisting of four treatments: control (no addition), Mycorrhiza (10 g·L^{-1}), *Trichoderma* (10 g·L^{-1}), and *Bacillus* (10 g·L^{-1}), denoted as M1, M2, M3, and M4, respectively. The second factor was foliar spray extracts: control (no addition), *Moringa* leaf extract (10 g·L^{-1}), and sprouted barley extract (100 g·L^{-1}), denoted as E1, E2, and E3, respectively. Treatment means were compared using the Least Significant Difference (L.S.D.) test at a 0.05 probability level. The results revealed that both individual and combined treatments showed statistically significant differences. The individual microbial treatment M4 demonstrated a significant superiority in plant height, number of branches, number of leaves, antioxidant content, and amino acid content in coriander plants, recording the highest values of 111.33 cm, 20.14 branches·plant^{-1}, 112.0 leaves·plant^{-1}, 62.51 mg·100g^{-1}, and 8.9722 mg·100g^{-1}, respectively. In contrast, the highest total yield was recorded by treatment M3, reaching 3652 kg·ha^{-1}.Foliar spray treatments also exhibited significant differences, with treatment E3 showing a significant increase in plant height, total yield, and amino acid content in coriander, recording maximum values of 108.50 cm, 3532 kg·ha^{-1}, and 8.9570 mg·100g^{-1}, respectively. Meanwhile, treatment E2 significantly improved the number of branches and antioxidant content, achieving the highest values of 19.21 branches·plant^{-1} and 61.61 mg·100g^{-1}, respectively. Regarding the interaction between microbial and foliar treatments, significant differences were also observed. The combined treatment M4E3 recorded the highest values in plant height, number of branches, and amino acid content, reaching 114.00 cm, 21.40 branches·plant^{-1}, and 9.0310 mg·100g^{-1}, respectively. In terms of number of leaves and antioxidant content, the highest values were observed in treatment M4E1, which reached 125.6 leaves·plant^{-1} and 65.44 mg·100g^{-1}, respectively.

Keywords: Bioactive compounds, Coriander, Organic extracts, Biofertilizers

Introduction
Coriandrum sativum L., commonly known as coriander, is an annual herbaceous plant belonging to the Apiaceae (Umbelliferae) family. It is characterized by a strong aromatic scent and can grow up to 50 cm in height. The plant has finely divided upper leaves and small white flowers. Coriander is widely recognized as a popular spice. Its native origin is believed to be Italy, and it is cultivated extensively across Mediterranean countries, as well as in India, South America, and Europe. It is grown both as a leafy vegetable—where its fresh leaves are used to enhance the flavor of dishes—and for its seeds, which are commonly used as a spice. The seeds contain essential oils ranging between 0.6-1%, the most significant of which include linalool (75%), borneol, geraniol, carvone, anethole, pinene, and limonene. Coriander essential oil is used medicinally as a carminative, analgesic, and for treating colic and irritable bowel syndrome (IBS). It also serves as a digestive stimulant, appetite enhancer, diuretic, and cholagogue. According to Simon *et al.* (1984) [30], coriander exhibits antispasmodic effects and regulates gastrointestinal activity, helping eliminate

excess salts, reduce the risk of thrombosis, and protect against inflammation due to its antioxidant content. It also lowers cholesterol levels and serves as a natural analgesic. The essential oil of coriander seeds is also employed in the cosmetic industry, perfumes, and certain soap varieties. Al-Dajwi (1996) [5] noted that coriander is a high-value leafy herb and one of the most widely cultivated herbs globally, with India, China, and Turkey being the largest producers and exporters. Different parts of the plant—fresh and dried leaves and seeds—are used in spice production. Green coriander leaves are rich in vitamin C (250 mg/100g) and carotene (2005 µg/100 g) (Chakravarty, 1976) [11]. The mature seeds contain water, fats, starch, sugar, proteins, fibers, and minerals such as calcium, phosphorus, and iron, along with essential oils (Diederichsen, 1996) [12]. Coriander also exhibits antibacterial and antifungal properties (Fleming, 1998) [15] and has a hypoglycemic effect (League of Arab States, 1988). In recent years, biofertilizers have been adopted as an alternative to chemical fertilizers. Interest in biofertilizer technologies and microbial inoculation of crops has grown as a sustainable approach to supply nutrients, partially mitigate nutrient deficiencies, and reduce reliance on chemical inputs, thereby minimizing environmental pollution. Biofertilization mechanisms include enhancing nutrient availability, producing growth-promoting substances, increasing nutrient uptake, and protecting the host plant from pathogens. Biofertilizers are cost-effective and safe, capable of reducing chemical fertilizer use by at least 25%, in addition to mitigating pollution problems (Al-Haddad, 1998) [6]. According to El-Shahat (2007) [13], biofertilizers should not completely replace chemical fertilizers but rather complement them by improving their efficiency and effectiveness. Another approach to reducing chemical fertilizer dependency is the use of plant-based extracts, particularly those derived from germinated seeds. These extracts have gained popularity due to their richness in compounds absent in mature plants, as well as their simple molecular forms that are readily absorbed. Germinated seeds are rich in gibberellins and low in abscisic acid, making their extracts abundant in natural growth-promoting hormones (Taiz), as well as easily absorbable nutrients, vitamins, amino acids, and sugars (Mandoki & Marton, 2010) [24]. These extracts can be applied directly to plants as foliar sprays. Furthermore, extracts from *Moringa* leaves (*Moringa oleifera*) are widely used due to their high content of proteins, calcium, potassium, magnesium, iron, carotenoids, cytokinins, and vitamins such as vitamin C and tocopherol. *Moringa* leaves contain plant-based compounds and hormones beneficial for plant growth, especially zeatin (a type of cytokinin), along with organic pigments like carotenoids, flavonoids, anthocyanins, niazimicin, glucosinolates, minerals, and sterols. These components contribute significantly to the plant's antioxidant capacity (Fuglie *et al*., 1999) [16].

Research Objectives

1. To evaluate the response of bioactive compounds in coriander (*Coriandrum sativum* L.) to foliar application of *Moringa* leaf extract and germinated barley seed extract.
2. To assess the influence of biofertilization treatments—including mycorrhiza, *Trichoderma*, and *Bacillus* species—on the accumulation of bioactive compounds in coriander.
3. To investigate the interaction effect between foliar organic extracts and biofertilizers on the levels of bioactive compounds in coriander plants.

Materials and Methods

The field experiment was conducted during the 2024-2025 growing season in the Al-Azawiya area, belonging to Al-Mahawil district, north of the Babil Governorate center. The study aimed to investigate the response of bioactive compounds in coriander (*Coriandrum sativum* L.) to foliar application of *Moringa* leaf extract and germinated barley seed extract, in addition to biofertilization treatments. The soil designated for the experiment was prepared by removing residues of the previous crop, followed by plowing, leveling, and smoothing operations to achieve a homogeneous seedbed. Drip irrigation was used to manage water supply throughout the experiment. Soil samples were randomly collected from a depth of 30 cm, air-dried, and thoroughly mixed to obtain a representative composite sample. Physical and chemical properties of the soil were analyzed at the Diwaniya Agriculture Directorate Laboratory. The experimental field was divided into three sectors, each containing 12 experimental units. Each unit measured 4 meters in length and consisted of three rows spaced 50 cm apart. Each row contained 8 plants, spaced 50 cm apart, resulting in 24 plants per experimental unit. A 1-meter buffer zone was left between the main plots. Coriander seeds were sown on October 6, 2024. The experiment was arranged in a Complete Randomized Blocks Design (CRBD) with a split-plot arrangement. Two factors were studied: microbial inoculants and foliar sprays of *Moringa* and germinated barley extracts. The main plots consisted of four microbial treatments: M1 (control, no inoculation), M2 (mycorrhiza), M3 (*Trichoderma*), and M4 (*Bacillus*). The subplots included three foliar spray treatments: E1 (spraying with water only), E2 (spraying with *Moringa* leaf extract at 10 $g \cdot L^{-1}$), and E3 (spraying with germinated barley extract at 100 $g \cdot L^{-1}$).

Preparation of *Moringa* Leaf Extract: Fresh *Moringa* leaves (10 g) were mixed with 100 ml of water (10 ml per 10 g fresh weight). The mixture was manually ground using a mortar and pestle to extract the juice, which was then filtered through a fine cloth. The filtrate was re-filtered to obtain a clear solution (Fuglie, 1999) [16]. The extract was diluted with distilled water at a ratio of 1:32 (v/v) and applied as a foliar spray to coriander plants within five hours of preparation. This extract contains amino acids, fatty acids, vitamins, nutrients, carbohydrates, and proteins. One thousand grams of barley seeds (Abha 265 cultivar) were washed and soaked in water for 24 hours, then drained and spread in a single layer on trays lined with cheesecloth in a dark place. The seeds were kept moist as needed to maintain hydration. After 72 hours, when the radicles emerged, the grains were germinated. The germinated seeds were thoroughly ground using an electric blender, filtered, and the volume was adjusted to 10 liters. The extract was used immediately for foliar spraying. It contains nitrogen, phosphorus, calcium, magnesium, iron, zinc, and gibberellins.

Experimental Measurements: On December 16, 2024, five plants were randomly selected from each experimental unit to measure plant height (cm), number of branches per plant,

and number of leaves per plant. Leaf samples were analyzed for total amino acid content (mg/100 g) according to Sadasivam and Manickam, and antioxidant content (mg/100 g) following the method described by Oyaizu (1986) [28].

Results and Discussion

Plant Height (cm)

The results presented in Table (1) indicate that there were significant differences among the microbial inoculation treatments in terms of plant height in coriander. The treatment M4 (*Bacillus*) recorded the highest plant height, reaching 111.33 cm, while the control treatment (M1) recorded the lowest height, at 104.56 cm. Similarly, significant differences were observed among foliar spray treatments, where treatment E3 (germinated barley extract) resulted in the highest average height of 108.50 cm, compared to the lowest value of 105.25 cm recorded in the control spray treatment (E1).Regarding the interaction between the two factors, the combination M4E3 exhibited a significant superiority, achieving the maximum plant height of 114.00 cm, followed by M4E1, which recorded 110.67 cm. On the other hand, the lowest plant height was observed in the control interaction treatment (M1E1), which recorded 99.33 cm.

Table 1: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on Plant Height in Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate M
M1	99.33	108.33	106.00	104.56
M2	108.00	108.67	102.67	106.44
M3	103.00	106.33	111.33	106.89
M4	110.67	109.33	114.00	111.33
Rate E	105.25	108.17	108.50	
L.S.D M=5.591		L.S.D E=3.060		L.S.D M*E=6.898

Total Number of Leaves (leaves·plant^{-1})

The results presented in Table (2) show that there were significant differences among the microbial inoculation treatments in terms of the total number of leaves per coriander plant. The treatment M4 (*Bacillus*) recorded the highest number, reaching 112.0 leaves·plant^{-1}, while the control treatment (M1) recorded the lowest number, at 100.1 leaves·plant^{-1}.In contrast, no significant differences were observed among the foliar spray treatments regarding the total number of leaves. As for the interaction between the two factors, the combination M4E1 showed a significant superiority, achieving the highest number of leaves, with 125.6 leaves·plant^{-1}, whereas the lowest value was recorded in the control interaction treatment (M1E1), with 86.9 leaves·plant^{-1}.

Table 2: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on the Number of Leaves in Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate M
M1	86.9	107.0	106.3	100.1
M2	95.9	91.1	92.2	93.2
M3	88.0	99.9	90.5	92.2
M4	125.6	103.2	107.0	112.0
Rate E	99.1	100.3	99.1	
L.S.D M=7.22		L.S.D E=9.47		L.S.D M*E=16.40

Total Number of Branches (branches·plant^{-1})

The results shown in Table (3) indicate the presence of significant differences among the microbial inoculation treatments with respect to the number of branches per coriander plant. The treatment M4 (*Bacillus*) recorded the highest number of branches, reaching 20.14 branches·plant^{-1}, followed by treatment M3 (*Trichoderma*), which recorded 19.61 branches·plant^{-1}.The results in the same table also show significant differences among the foliar spray treatments, where E2 (*Moringa* leaf extract) achieved the highest value of 19.21 branches·plant^{-1}, while the control treatment (E1) recorded the lowest value of 17.72 branches·plant^{-1}.Regarding the interaction between the two studied factors, the combination M4E3 resulted in the highest number of branches, reaching 21.40 branches·plant^{-1}, followed by M3E3, which recorded 20.67 branches·plant^{-1}. In contrast, the lowest number was recorded in the control interaction treatment (M1E1), with 14.83 branches·plant^{-1}.

Table 3: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on the Number of Branches in Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate M
M1	14.83	19.13	19.13	17.69
M2	17.30	19.23	15.03	17.19
M3	19.40	18.77	20.67	19.61
M4	19.33	19.70	21.40	20.14
Rate E	17.72	19.21	19.09	
L.S.D M=0.780		L.S.D E=0.902		L.S.D M*E=1.590

Total Yield per Unit Area (kg·ha^{-1})

The results presented in Table (4) indicate the presence of significant differences among the microbial inoculation treatments in terms of total yield per hectare. The treatment M3 (*Trichoderma*) recorded the highest yield, reaching 3652 kg·ha^{-1}, followed by treatment M2 (Mycorrhiza), which recorded 3529 kg·ha^{-1}. In contrast, the control treatment (M1) recorded the lowest yield, with 2857 kg·ha^{-1}.The results also show significant differences among the foliar spray treatments. The treatment E3 (sprouted barley extract) achieved the highest yield, with 3532 kg·ha^{-1}, while the control foliar spray (E1) recorded the lowest yield, at 3147 kg·ha^{-1}.However, the interaction between the two factors (microbial inoculation × foliar spray) did not show significant differences in total yield.

Table 4: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on Total Vegetative Yield of Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate M
M1	2299	3058	3214	2857
M2	3371	3404	3811	3529
M3	3299	3896	3761	3652
M4	3618	2998	3343	3320
Rate E	3147	3339	3532	
L.S.D M=404.5		L.S.D E=350.3		L.S.D M*E=700.6

Discussion of Results

The observed increase in vegetative growth parameters of coriander plants (such as plant height, number of leaves, number of branches, and total yield) as a result of treatments with biofertilizers and foliar sprays can be attributed to the multifaceted effects of these inputs. Arbuscular mycorrhizal fungi (AMF) play a pivotal role in improving soil physical

properties by binding soil particles and retaining organic matter. They exhibit numerous positive effects on plant nutrition by enhancing nutrient uptake, particularly potassium and sodium, thus promoting overall plant growth. Additionally, AMF significantly contribute to phosphorus availability in the soil, improve root development, and enable roots to access soil regions otherwise difficult to reach (Kumar *et al*., 2019; Pandey *et al*., 2019) [22, 29]. *Trichoderma* spp. enhance root and shoot development, increase plant productivity, improve nutrient uptake, and boost plant resistance to various environmental stresses such as temperature, humidity, and soil salinity. Their role as biological control agents is due to their mechanisms, including activation of plant defense systems, mycoparasitism, secondary metabolite production, and improved root efficiency. As biofertilizers, they increase nutrient uptake, promote crop yield, enhance stress tolerance, and induce seed germination (Kumar *et al*., 2019; Japanis *et al*., 2022) [22, 20]. The treatment with *Bacillus* spp.—beneficial root-colonizing bacteria—has shown to significantly stimulate plant growth and yield when applied to seeds or roots. These bacteria can solubilize insoluble phosphate minerals, making them available for root absorption, and also produce growth hormones and antibiotics. In coriander, the combination of *Bacillus* and fungi led to notable increases in vegetative growth traits, such as plant height, number of branches, and dry biomass. The addition of biofertilizers notably improved nutrient concentration in the leaves, particularly potassium. This can be attributed to the microorganisms' ability to secrete organic acids and growth regulators that positively influence plant development. These findings are consistent with those of Ali *et al*. (2023) [7]. The positive effects of biofertilizers on plant development are also due to their role in improving soil fertility by releasing organic acids that lower soil pH, thereby converting nutrients into forms accessible to plant roots. This leads to better stem elongation and overall plant height. Biofertilizers also stimulate branching and enhance enzymatic activity that drives photosynthesis, resulting in greater production of nutritional compounds. This promotes vegetative traits by stimulating bud growth, especially due to the presence of humic and fulvic acids, ultimately improving foliage and vegetative yield. Plants respond favorably to bacterial inoculation, particularly in seed germination, root development, and leaf area (Abdel Salam *et al*., 2022; Suleiman, 2018; Mounika, 2017; Abdulaziz) [2, 31, 27,]. These findings are also supported by Metwaly and Abd-El-Sayed (2018) [26] in basil.As for foliar spray treatments, both *Moringa* leaf extract (MLE) and sprouted barley extract have proven to enhance and promote plant growth. These aqueous extracts are rich in minerals such as potassium, calcium, and iron, making them excellent growth stimulators. A study on *Vigna unguiculata* (cowpea) demonstrated that MLE application significantly improved overall plant growth. MLE is known to contain high levels of phytohormones—especially zeatin, along with auxins, cytokinins, and gibberellins—which, combined with essential nutrients, contribute to enhanced crop development. MLE has been shown to significantly increase vegetative traits such as plant height and branch number in *Eruca sativa* (arugula), thanks to its content of vitamins, amino acids, and nutrients. Foliar application of MLE on *Capsicum annuum* (pepper) under greenhouse conditions also resulted in improved vegetative parameters, including plant height and branch number. These findings are in agreement with Maishanu *et al*. (2017) [23], Abd-ElKafie *et al*. (2016) [3], Al-Tufaili (2023) [8], and Mahdawi *et al*. (2023) [25]. Sprouted barley seed extract, rich in essential minerals such as calcium, phosphorus, potassium, and nitrogen, along with carbohydrates and proteins, is also a potent source of natural plant hormones that promote growth. The application of barley extract significantly improved vegetative parameters in coriander, including plant height, number of branches, and dry matter percentage. The benefits of seed sprouting extend beyond basic germination, enhancing bioavailability and the absorbability of nutrients, vitamins, amino acids, and sugars by living tissues (Marton & Mandoki, 2010) [24]. Sprouted seeds also contain high levels of gibberellins and low levels of abscisic acid, making them a rich source of natural growth stimulants (Bhatia & Lal, 2019) [10].

Total Amino Acids (mg·100g^{-1})

The results in Table (5) indicate the presence of significant differences among the microbial inoculation treatments regarding total amino acid content in coriander leaves. The M4 treatment (*Bacillus*) recorded the highest concentration, reaching 8.9722 mg·100g^{-1}, while the control treatment (M1) recorded the lowest value at 8.9116 mg·100g^{-1}.Similarly, significant differences were observed among the foliar spray treatments. The E3 treatment (sprouted barley extract) showed the highest amino acid content, with 8.9507 mg·100g^{-1}, whereas the control spray (E1) recorded the lowest value at 8.9203 mg·100g^{-1}.Regarding the interaction between the two factors, the combination M4E3 showed a significant superiority, recording the highest value of 9.0310 mg·100g^{-1}, followed by M4E2 with 8.9653 mg·100g^{-1}. In contrast, the control treatment combination recorded the lowest value, 8.8823 mg·100g^{-1}.

Table 5: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on Total Amino Acids Content in Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate E
M1	8.8823	8.9373	8.9150	8.9116
M2	8.9207	8.9177	8.9267	8.9217
M3	8.9577	8.9037	8.9300	8.9304
M4	8.9203	8.9653	9.0310	8.9722
Rate E	8.9203	8.9310	8.9507	
L.S.D M=0.02425		L.S.D E=0.02002		L.S.D M*E=0.03802

Discussion of Results

The results indicated that the application of bio-fertilizers and foliar extracts led to a significant increase in the amino acid content of coriander plants compared to untreated controls. This increase may be attributed to the presence of beneficial microorganisms and their effective role in promoting plant growth, as well as the nutrients, vitamins, and phytohormones they provide, which contribute to enhancing amino acid levels in coriander tissues. Bio-fertilizers play a vital role in improving plant growth and increasing physiological efficiency. One of their most notable effects is the enhancement of free amino acids, which are essential for the synthesis of proteins, enzymes, and other bioactive compounds. Beneficial microorganisms such as *Trichoderma* spp., *Bacillus* spp., and arbuscular mycorrhizal fungi (AMF) have shown a strong capacity to

stimulate the accumulation of amino acids by improving nitrogen uptake and activating metabolic processes. Studies have reported that *Trichoderma* enhances primary metabolism, including the biosynthetic pathways of amino acids such as glutamine and proline, through the secretion of plant growth regulators and active enzymes (Harman *et al*., 2004). Likewise, *Bacillus* contributes to the production of auxins and improves the uptake of both micro- and macronutrients, thereby increasing the levels of amino acids—especially those associated with stress tolerance, such as proline and aspartic acid (Idris *et al*., 2007) [19]. On the other hand, arbuscular mycorrhizal fungi (AMF) enhance the absorption of phosphorus and water, which indirectly supports the biochemical processes involved in amino acid synthesis. Experimental evidence on medicinal and aromatic plants—including coriander—shows that AMF inoculation increases the content of free amino acids and total protein in leaves and seeds compared to non-inoculated plants (Giri *et al*., 2005; Kapoor *et al*., 2004) [17, 21]. Moreover, foliar application of plant extracts also resulted in a significant increase in amino acid levels. This increase is likely due to the bioactive compounds found in plant-based extracts, including hormones, vitamins, and nutrients, particularly those derived from biologically rich sources such as *Moringa*, barley, or yeast. These components stimulate metabolic processes within the plant, including the biosynthesis of proteins and amino acids. It is also likely that the organic compounds, vitamins, and minerals in these extracts enhanced enzymatic activities related to amino acid biosynthesis. Additionally, plant extracts help improve nitrogen absorption and boost cellular activity, leading to higher amino acid concentrations in plant leaves, consistent with the findings of El-Sherbeny *et al*. (2007) [14].

Total Antioxidant Capacity (mg·100g^{-1})

The results in Table (6) reveal significant differences among the microbial inoculation treatments in terms of total antioxidant capacity in coriander leaves. The M4 treatment (*Bacillus*) exhibited the highest value, reaching 62.51 mg·100g^{-1}, followed by M3 (*Trichoderma*) with 61.61 mg·100g^{-1}, whereas the control treatment (M1) recorded the lowest value at 53.41 mg·100g^{-1}.Significant differences were also observed among the foliar spray treatments, where E2 (*Moringa* leaf extract) resulted in the highest antioxidant content at 61.61 mg·100g^{-1}, while the control spray (E1) recorded the lowest value of 58.19 mg·100g^{-1}.Regarding the interaction effect between the microbial inoculants and foliar sprays, the combination M4E1 achieved significant superiority, yielding the highest antioxidant capacity of 65.44 mg·100g^{-1}, followed by M3E1 with 63.15 mg·100g^{-1}, whereas the control combination recorded the lowest value, 46.51 mg·100g^{-1}.

Table 6: Effect of Biofertilizers, Foliar Spray Extracts, and Their Interaction on Total Antioxidant Content in Coriander (*Coriandrum sativum* L.)

ME	E1	E2	E3	Rate M
M1	46.51	60.05	53.67	53.41
M2	57.66	61.41	59.67	59.58
M3	63.15	62.62	59.06	61.61
M4	65.44	62.35	59.75	62.51
Rate E	58.19	61.61	58.04	
L.S.D M=4.734		L.S.D E=2.293		L.S.D M*E=5.553

Discussion of Results

The findings of the current study demonstrated that the application of bio-fertilizers and foliar extracts led to a significant increase in antioxidant content in coriander plants compared to untreated controls. This increase in the concentration of antioxidants, such as total phenolics and flavonoids, may be attributed to the vital role played by the microorganisms present in bio-fertilizers in enhancing the uptake of essential nutrients, particularly nitrogen and phosphorus, which are critical for metabolic processes. Moreover, the positive interaction between beneficial microbes and plant roots contributes to the stimulation of enzymes involved in the biosynthetic pathways of antioxidant compounds, such as phenylalanine ammonia-lyase (PAL). This supports the hypothesis that the role of bio-fertilization extends beyond improving vegetative growth to enhancing the phytochemical quality of the plant. The increase in antioxidant content and oxidative activity in the vegetative parts of the plant may also be a cumulative result of improved vegetative indicators due to bio-fertilization, which led to increased accumulation of dry matter. This enhancement is primarily driven by elevated rates of photosynthesis, which produce primary metabolites, and consequently increase the accumulation of intermediate compounds that participate in secondary metabolism for the synthesis of phenolic and flavonoid compounds. Furthermore, the observed correlation between increased vegetative growth indicators and enhanced photosynthetic activity may reflect a heightened demand of the biological system for antioxidant compounds. These compounds are essential for maintaining enzymatic reactions involved in biomass production and for protecting against free radicals and reactive oxygen species generated during energy transfer reactions. This relationship is particularly evident when bio-inoculation is accompanied by elevated levels of ascorbic acid, which plays a crucial role in the Ascorbate-Glutathione Cycle in combating intracellular H_2O_2 resulting from intensified metabolic activity. The simple linear correlation between vegetative growth parameters and the content of phenolics, flavonoids, carotenoids, and antioxidant activity is statistically expressed as a strong positive association (Al-Asadi, 2018) [4]. In addition, treatments with foliar extracts of *Moringa* and barley also led to a significant increase in total antioxidant content in coriander plants. This improvement may be attributed to the rich content of these extracts in nutrients, amino acids, vitamins, and plant hormones, which serve as a good reservoir of growth-promoting substances. Moreover, the integration of such natural inputs into plant nutrition management can have a pronounced effect on the quality and composition of bioactive compounds within the plant.

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