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Research Article
Effects of Iron (II) Sulfate and Potassium Humate on Growth and Chemical Composition of *Coriandrum sativum* L.

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Abstract
Background and Objective: Coriander (*Coriandrum sativum* L.), is an annual herb related to the *Apiaceae* family. Coriander is one among the prime vital sources of medicines as natural synonyms to synthetic components, used for cure of many human disorders, in cosmetics and as a flavored agent in food merchandise. The purpose of present investigation was to study the effects of foliar spraying of iron (II) sulphate ($FeSO_4$) and potassium humate solely or combinations at different concentrations of them on different growth parameters as flowering, yield, essential oil content and chemical composition of coriander plants. **Materials and Methods:** This study was conducted in open fields for two seasons continuously to study the effects of $FeSO_4$ and potassium humate on growth parameters, floral characteristics, essential oil content, chemical composition of essential oil, chemical constituents, the contents of chlorophyll a and b, total carotenoids, total carbohydrate (%) and nutrient contents of coriander plant. The layout of the experiment used was "factorial experimental" in complete randomized block design system with 3 replicates. Data recorded were subjected to the two-way analysis of variance according to Snedecor and Cochran. **Results:** The observed data cleared that spraying potassium humate and ($FeSO_4$) gave high increasing on contents of chemical constituents (N, P, K %) in the herb and the seeds. Increased Fe (ppm) content in leaves and seeds also increased the total chlorophyll a and b, carotenoids, the total carbohydrates content, the herb essential oil yield in seeds and its chemical constituents (%) in comparison to the control plants in two successive seasons. **Conclusion:** Generally, both potassium humate and $FeSO_4$ together are perfect fertilizers for good growth of the coriander herb and seed yields with suitable content of essential oil.

Key words: Coriander, FeSO4, potassium humate, fertilizer, chemical composition

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Coriander (*Coriandrum sativum* L.), is an annual herb relevant to the *Apiaceae* family. It is domesticated to Mediterranean regions and cultivated for the fresh green herb and the fruits which are used for producing of essential oils[1] as a flavour agent in food merchandise[2]. Coriander is one among the foremost vital sources of medicines as natural alternatives to artificial compounds[3]. Furthermore, this plant has been employed to cure diseases like alimentary tract disorders, respiratory tract disorders and urinary tract infections and others[4-6]. Coriander has been identified as one of the herbs that can be used to treat diabetes and its leaves have shown stronger antioxidant activity than the seeds[7-9]. Coriander was reported to boost blood circulation to the brain and recover memory capabilities[10], possess antihyperlipidemic[11] and antimicrobial activity[12]. Additionally, the fruit essential oil was used as a typical ingredient in creams, detergents, surfactants, emulsifiers, perfumes and cosmetics[13].

Humic substances (HS) are major elements of the natural organic matter (NOM) in soil, water and in geologic organic precipitates like lake sediments, peats, brown coals and shales. Humic substances affect physical and chemical properties and improve soil fertility. Such substances play important role on improving plant growth, accelerate cell division, affect both respiration and photosynthesis, affect pH and alkalinity and affect the chemistry, cycling and bioavailability of chemical elements as well as transport and degradation of xenobiotic and natural organic chemicals[14-21].

Potassium humate can be used as an organic potash fertilizer to supply the plants with high levels of soluble potassium in a readily available form. Combined with humic acid, potassium can be rapidly absorbed and incorporated into plants. Potassium humate increases photosynthesis, chlorophyll density and plant root respiration, which resulted in greater plant growth and yield[22-28].

Micronutrient as iron (Fe) fertilizer is the promotion of growth and production of some medicinal and aromatic plants such as coriander, anise, sweet fennel, peppermint, lemon balm and chamomile[8,29-33].

The purpose of present investigation was to study the effects of iron (II) sulfate ($FeSO_4$) and potassium humate application method (foliar spraying) solely or combination with different concentrations of them on various growth parameters as flowering, yield, essential oil content and chemical composition of Coriander plants.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental farm "Demo" in Faculty of Agriculture, Fayoum University, during two successive seasons of 2013/2014 and 2014/2015 to study the effects of iron (II) sulfate ($FeSO_4$) and potassium humate on growth and chemical composition of *Coriandrum sativum* L. Prior to any practices, a composite soil sample was taken from the soil surface (0-30 cm) of the experimental site, air-dried, sieved by 2 mm sieve and analyzed and recorded in Table 1. The physical and chemical properties of soil were determined according to Klute[34] and Page *et al*.[35].

Seeds of coriander were obtained from Research Center of Medicinal and Aromatic Plants, Ministry of Agriculture, Egypt. Seeds were sown on 7th and 8th of October (for two seasons, respectively). Five seeds were sown in each hill at 25 cm apart and then the propagated plants were thinned to 2 plants at the age of 30 days. Plants received the normal agricultural practices as needed. The layout of the experiment used was "factorial experimental" in complete randomized block design system with three replicates. Each replicate contained 3 plots each plot contained five rows each row was 60 cm a part and 2.1 m in length. The plot area was ($2.1\ m \times 3\ m = 6.3\ m^2$). All the plants received recommended agriculture practices. Foliar spray of potassium humate (65% humic acid) at rates of 0, 1, 2 and 3 g L^{-1} and ($FeSO_4$) were applied at rates of 0, 1, 2 and 3%. The treatments were applied three times on the plants; the first time at 30 days after sowing and the second is 1 month after the first and the second application. The control plants were sprayed with distilled water.

Vegetative growth and yield characters: At the age of 170 days (during vegetative stage), the outer 2 rows (1st and 5th) of each plot were chosen from each experimental unit and cut off at ground level and submitted to the following determinations; plant height (cm), number of branches/plant, fresh and dry matters/plant (g), at full maturity fruit stage (220 days), the central ridges were chosen from each experimental unit, to estimation the following yield characters: Number of umbels/plant, mass of seeds (fruits) in (g) and mass per plant (g).

Chemical constituents:

- Chlorophyll a, b and total carotenoids in leaves were determined using the method described by Lichtenthaler[36]

Table 1: Characteristics of the soil from experimental site

	Mechanical analysis			
Years	Sand (%)	Silt (%)	Clay (%)	Texture class
2013/2014	78.00	13.00	9.00	Sandy loam
2014/2015	77.00	14.00	9.00	Sandy loam

	Available nutrients									
			N	P	K	Fe	Mn	Zn	Mg	
Years	Soil pH	ECe	mg kg^{-1}							$CaCo_3$ (%)
2013/2014	7.84	3.74	17.58	9.71	1.64	2.22	4.81	0.31	8.71	10.31
2014/2015	7.88	3.79	18.69	8.89	1.68	2.28	5.96	0.37	8.77	9.98

ECe: Electrical conductivity of the saturation extract of the soil

- Total carbohydrates content in herb (%) in powdered dry matter of herb determined color-metrically according to Herbert *et al.*[37]
- Extraction of essential oil: Fruits (seeds) hydro-distillation for 3 h using a Clevenger type apparatus[38]
- Total N, P and K, in herbs and seeds as well as iron content were determined according to methods described by Cottenie *et al.*[39]

Statistical analysis: The means of data recorded in the two successive seasons were subjected to the two-way analysis of variance according to Snedecor and Cochran[40]. The least significant differences (LSD) at $p = 0.05$ level was used to verify the differences between means of the treatments.

RESULTS AND DISCUSSION

Effect of ($FeSO_4$) and potassium humate on vegetative growth parameters of coriander plants: The application foliar spray of ($FeSO_4$) and potassium humate showed superior effect in the parameters tested (Plant height, number of branches/plant, fresh and dry matters/plant (g), number of umbels/plant, seeds (fruits) mass/plant (g) as compared to the control which not received ($FeSO_4$) and potassium humate in both season. These results are an agreement with those obtained by Carrubba[14], Prakash *et al.*[24], Barakat *et al.*[25], Kalidasu e*t al.*[29] and Nasiri e*t al.*[31]. Increasing growth parameters and yield may be due to that humic acid plays a main role in improving chlorophyll pigments and consequently, increases photosynthesis a plant production because they are hormone-like substances as reported by Nardi *et al.*[18] and Yang e*t al.*[28]. It is worth to mention that the data of the two seasons in Table 2 cleared that the tested growth parameters gave maximum value with adding potassium humate alone at a rate of (3 g L^{-1}) giving plant the best height, high numbers of branches, big masses of fresh matter or dry matter, big numbers of umbels and big mass of seeds as in agreement with Danyaei *et al.*[19] and Hashish *et al.*[26]. Moreover, application foliar spray of ($FeSO_4$) at a rate of 2% as sole gave the highest values of plant height, number of branches, fresh matter, dry matter, number of umbels and mass of seeds as compared to the control values of the tested parameters in both seasons and as in agreement with Patil *et al.*[23]. It could be said that application of such substances increased all the growth parameters tested of coriander plants and that may be due to the improved ability of the crop to absorb nutrients, photosynthesis and catalytic activity and breakdown of complex substances into simple forms like glucose, amino acids and fatty acids[8] . In addition Singh[32], who found that ferrous sulphate applied 0.5% at 45 and 60 days after sowing resulted into maximum coriander plant height and yield. Data also showed that foliar spray of ($FeSO_4$) with potassium humate was significant increased $p = 0.05$ growth parameters and seeds yield as compared to foliar spray of ($FeSO_4$) and potassium humate alone and the control treatment in both seasons. Results of this experiments showed that the highest value of plant height , number of branches, fresh matter and dry matter were produced by combination of ($FeSO_4$) with potassium humate at a rate of 3% +3 g L^{-1}, respectively. While the highest number of umbels and mass of seeds, were produced by combination of ($FeSO_4$) with potassium humate at a rate of 2% +3 g L^{-1}, respectively in both seasons. These findings are in conformity with Rubio *et al.*[41], who found that humic substances have an important ability to be chelating agents to protect the micro nutrients from leaching but weak enough to release micro nutrients to plants when required.

Essential oil content and chemical composition of essential oil: The response of essential oil yield/plant (%) of coriander plant to the ($FeSO_4$) and potassium humate fertilizers as alone or together as shown in Table 3. The data indicated that all

Table 2: Effect of foliar application of $FeSO_4$ and potassium humate on various growth parameters of coriander plants at two seasons

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
Plant height (cm)										
0	26.33	29.00	32.67	31.67	29.92	30.59	39.41	35.79	40.66	36.61
1	30.00	32.33	31.67	38.00	33.00	31.38	39.77	43.22	42.34	39.18
2	33.67	33.00	38.33	36.00	35.25	42.56	45.31	42.63	45.26	43.94
3	27.67	39.33	30.67	39.33	34.25	38.52	38.29	44.40	46.93	42.04
Mean	29.42	33.42	33.34	36.25		35.76	40.70	41.51	43.80	
LSD 5%	a: NS, b: 3.29, axb: 6.58					a: NS, b: 2.09, axb: 4.17				
Branches number/plant	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	2.33	3.00	5.00	4.33	3.67	3.38	4.25	6.23	5.33	4.80
1	3.67	4.33	4.00	5.31	4.33	3.70	5.29	5.18	6.44	5.15
2	4.33	5.67	4.77	5.00	4.94	5.21	5.31	6.30	6.27	5.77
3	4.00	5.00	4.33	5.33	4.66	4.53	6.49	5.39	6.52	5.73
Mean	3.58	4.50	4.53	4.99		4.21	5.34	5.78	6.14	
LSD 5%	a: 0.61, b: NS, axb: 1.23					a: 0.14, b: 0.14, axb: 0.29				
Fresh matter/plant (g)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	6.84	7.57	8.09	9.46	7.99	6.90	8.69	8.54	9.38	8.38
1	6.87	9.97	12.13	12.25	10.31	7.14	9.98	10.95	12.58	10.16
2	9.14	10.60	12.62	14.73	11.66	9.40	12.37	14.44	12.27	11.57
3	8.67	11.89	14.08	16.91	13.01	8.55	11.66	14.20	16.60	12.97
Mean	7.88	10.01	11.73	13.34		7.66	10.68	12.03	12.71	
LSD 5%	a: NS, b: NS, axb: 5.74					a: 0.26, b: 0.27, axb: 0.54				
Dry matter/plant (g)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	1.59	1.85	2.05	2.35	1.96	1.59	1.88	2.85	2.28	2.15
1	2.16	2.63	2.80	3.25	2.71	1.86	2.67	2.47	3.29	2.57
2	2.51	3.00	3.17	3.27	2.99	1.89	3.26	3.11	3.43	2.92
3	2.45	3.73	3.88	4.34	3.60	3.45	2.35	3.89	4.33	3.51
Mean	2.18	2.80	2.98	3.30		2.20	2.54	3.08	3.33	
LSD 5%	a: NS, b: NS, axb:1.43					a: 0.26, b: 0.26, axb: 0.52				
Number of umbels/plant	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	4.99	5.00	6.67	8.00	6.17	5.29	5.74	6.42	7.16	6.15
1	5.00	6.67	7.67	8.33	6.92	5.71	7.37	7.49	8.44	7.25
2	7.67	9.67	10.41	11.12	9.72	7.30	10.41	7.43	11.76	9.23
3	6.33	8.00	9.67	9.67	8.42	6.38	8.58	6.52	9.47	7.74
Mean	6.00	7.34	8.61	9.28		6.17	8.03	6.97	9.21	
LSD 5%	a: 1.94, b: NS, axb: 3.87					a: 0.45, b: 0.45, axb: 0.89				
Fruit mass/plant (g)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	3.61	4.19	5.10	4.89	4.45	3.68	3.82	3.84	4.78	4.03
1	3.62	4.27	4.32	4.90	4.28	3.89	3.78	3.96	3.86	3.87
2	4.60	4.29	5.56	5.76	5.05	4.20	4.42	4.51	5.15	4.49
3	4.20	4.22	4.15	5.03	4.40	3.68	4.11	4.28	4.92	4.25
Mean	4.01	4.24	4.78	5.15		3.79	4.03	4.15	4.68	
LSD 5%	a: 0.57, b: NS, axb: NS					a: NS, b: NS, axb: 0.85				

treatments under study significantly increased p = 0.05 the essential oil/plant percentage overcame the control treatment in both seasons. Obtained results agreed with those of Rathore *et al.*[6], Nasiri *et al.*[31] and Zehtab-Salmasi *et al.*[33]. The highest values of essential oil, percentage were recorded with the combination of ($FeSO_4$) and potassium humate as 2% +2g L^{-1}, respectively, that significantly overcame the other treatments and the lowest with control treatment. The effect of ($FeSO_4$) and potassium humate on the chemical composition of essential oil extracted from the coriander seeds was indicated in Table 4. The variations in chemical composition are important between the treatments. All the treatments of ($FeSO_4$) and potassium humate increased the major constituents of essential oil

Table 3: Effect of foliar application of $FeSO_4$ and potassium humate on the essential oil yield/plant (%) of coriander plants at two seasons

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
Essential oil yield/plant (%)										
0	1.26	1.37	1.4	1.64	1.42	1.26	1.26	1.39	1.44	1.34
1	1.33	1.47	1.8	1.61	1.55	1.26	1.43	1.54	1.70	1.48
2	1.46	1.53	1.92	1.84	1.69	1.38	1.64	1.84	1.73	1.65
3	1.38	1.56	1.69	1.75	1.60	1.33	1.50	1.62	1.78	1.56
Mean	1.36	1.48	1.70	1.71		1.31	1.46	1.60	1.66	
	a: 0.04, b: 0.04, axb: 0.09					a: 0.05, b: 0.05, axb: 0.11				

Table 4: Effect of foliar application of ($FeSO_4$) and potassium humate on chemical constituents (%) of seed essential oils of coriander plants

	Treatments potassium humate+$FeSO_4$						
Chemical constituents (%)	0 g L^{-1}+0%	3 g L^{-1}+1%	3 g L^{-1}+2%	3 g L^{-1}+3%	2 g L^{-1}+1%	2 g L^{-1}+2%	2 g L^{-1}+3%
Alcohols							
Linalool	57.73	66.33	78.11	71.34	67.88	75.26	73.79
Geraniol	1.37	2.22	4.27	4.14	2.84	1.99	3.78
Terpinen-4-ol	1.03	1.35	3.05	1.89	1.67	2.45	1.93
α-terpineol	0.21	0.34	0.42	0.48	0.51	0.27	0.37
Citronellol	0.98	1.06	1.39	1.25	1.11	1.44	1.38
Hydrocarbons							
ϒ-terpinene	8.22	11.26	12.27	10.37	9.17	9.48	10.82
r-cymene	3.26	4.50	7.36	6.61	4.14	3.35	5.11
Limonene	2.05	2.41	5.09	3.96	3.16	4.23	2.91
α-pinene	6.33	9.00	8.33	6.88	8.14	6.69	7.42
camphene	1.13	1.74	1.87	1.85	1.47	1.62	1.94
Myrcene	1.29	1.30	1.81	1.57	1.31	1.42	1.52
α-cedrene	2.91	4.14	4.57	4.29	4.37	4.14	3.91
α-farnesene	1.31	1.54	2.37	2.24	1.96	1.88	1.87
B-sesquiphellandrene	1.09	1.51	1.87	1.95	1.47	1.17	1.63
Ketones/Esters							
Camphor	1.98	2.36	5.57	4.23	4.35	3.38	5.17
Geranyl acetate	1.95	2.62	4.81	5.27	2.49	2.71	3.31
Linalyl acetate	1.89	2.66	3.09	2.48	2.57	3.02	2.67
Citronellyl acetate	1.36	1.64	2.38	2.23	1.63	2.00	1.77

extracted from coriander seeds compared with the control. These results are in accordance with those obtained by Moraes *et al.*[42]. Data in fractional composition also show that linalool (78.11%) was the basic component and was followed by ϒ-terpinene (12.27%) with ($FeSO_4$) and potassium humate as 2% +3 g L^{-1} treatment and α-pinene (9%) of the chemical profile of coriander essential oil with ($FeSO_4$) and potassium humate as 1% +3 g L^{-1} treatment as compared with the other treatment and control. The results of present study are in agreement with Carrubba *et al.*[43]. In this respect Shajari *et al.*[27] referred that the highest essential oil percentage and essential oil yield were observed in mycorrhizae and mycorrhizae with chemical fertilizer treatments.

Photosynthesis pigments: The application foliar spray of ($FeSO_4$) and potassium humate used in the current study showed a significantly positive effect p = 0.05 on increasing the contents of chlorophyll a and b, total carotenoids and total carbohydrate (%) with all the treatments as compared with the values recorded of control coriander plants in both season. Data presented in Table 5 is in agreement with Tejada and Gonzalez[44] and cleared that performance, chlorophyll content, carotenoids increased in *Asparagus officinalis* with application of humic acid.

Nutrient content: As displayed in Table 6, 7 it was observed that spraying potassium humate and ($FeSO_4$) gave high significantly increased p = 0.05 on contents of chemical constituents (N, P, K%) in the herb and the seeds and Fe (ppm) content in leaves and seeds of coriander plants in both seasons in comparison to the control plants. These results are in agreement with those found by Tejada and Gonzalez[44], who found increased macro-and micro-nutrients in *Asparagus officinalis* with using humic acid.

Nitrogen content in herb and seeds increased with spray of ($FeSO_4$) with potassium humate at rate of 3% +3 g L^{-1}, respectively and the lowest values were obtained with spray of ($FeSO_4$) with potassium humate at rate of 1% +1 g L^{-1}, respectively in both seasons. The same trends were obtained in concentration of (Fe) in leaves and seeds. Data in Table 6, 7 showed also that the highest values of phosphorus and potassium contents (%) in herb and seeds were recorded by foliar spray of ($FeSO_4$) with potassium humate at rate of 2% +3 g L^{-1}, respectively in both seasons. Whereas spray of ($FeSO_4$) with potassium humate at rate of 3% +1 g L^{-1}, respectively gave the lower values of phosphorus and potassium content in herb and seeds as compared with other treatments. In this respect Shajari *et al*.[27] showed that the combined of chemical fertilizer and manure improved crop yield by increasing the efficiency of nutrient absorption for plants.

In this respect, Mahmoud and Amira[45] detected that the addition mixture of (cattle manure+zeolite+humic substances+magnetite) will improve the plant growth parameters also the plant chemical compensations better than using the chemical fertilizers. Implication of these results indicate the role of a mixture of $FeSO_4$ and potassium humate as foliar spry in growth, development of coriander plants and increasing amount of the essential oil. It is recommended to use safe foliar spray as fertilizer on the plants rather to use manure in fertilization according to its hazards of disease transfer to human or animals.

Table 5: Effect of foliar application of $FeSO_4$ and potassium humate on photosynthesis pigments and total carbohydrate of coriander plants at two seasons

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
Chlorophyll a (mg g^{-1} F.M.)										
0	1.35	1.59	1.40	1.46	1.45	1.37	1.61	1.43	1.48	1.47
1	1.37	1.56	1.65	1.76	1.59	1.39	1.67	1.58	1.78	1.61
2	1.43	1.46	1.63	1.70	1.56	1.46	1.48	1.66	1.73	1.58
3	1.49	1.61	1.72	1.85	1.67	1.52	1.63	1.75	1.87	1.69
Mean	1.41	1.56	1.60	1.69		1.44	1.60	1.61	1.72	
LSD 5%	a: 0.01, b: 0.01, axb: 0.02					a: 0.01, b: 0.01, axb: 0.02				
Chlorophyll b (mg g^{-1} F.M.)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	0.79	1.08	0.90	1.00	0.94	0.80	1.08	0.90	1.00	0.95
1	0.81	1.05	1.12	0.99	0.99	0.81	1.05	1.13	0.99	1.00
2	1.03	0.94	1.10	1.21	1.07	1.03	0.94	1.10	1.21	1.07
3	0.84	1.12	1.20	1.16	1.08	0.85	1.13	1.20	1.16	1.09
Mean	0.87	1.05	1.08	1.09		0.87	1.05	1.08	1.09	
LSD 5%	a: 0.04, b: 0.04, axb: 0.08					a: 0.03, b: 0.03, axb: 0.07				
Total carotenoids (mg g^{-1} F.M.)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	0.38	0.53	0.50	0.47	0.47	0.40	0.55	0.52	0.50	0.49
1	0.43	0.56	0.48	0.77	0.56	0.45	0.58	0.51	0.80	0.59
2	0.47	0.49	0.55	0.64	0.54	0.50	0.51	0.57	0.67	0.56
3	0.54	0.56	0.58	0.50	0.55	0.57	0.58	0.61	0.52	0.57
Mean	0.46	0.54	0.53	0.60		0.48	0.56	0.55	0.62	
LSD 5%	a: 0.04, b: 0.03, axb: NS					a: 0.04, b: 0.03, axb: NS				
Total carbohydrate (%) in herb	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	21.50	27.20	28.80	29.70	26.80	21.50	27.90	28.80	27.80	26.50
1	26.90	27.60	30.10	29.00	28.40	24.90	28.20	31.40	31.50	29.00
2	28.20	28.10	31.20	28.60	29.03	29.90	30.10	32.10	30.90	30.75
3	28.00	29.20	30.90	27.80	28.98	28.00	25.40	30.20	28.90	28.13
Mean	26.15	28.03	30.25	28.78		26.08	27.90	30.63	29.78	
LSD 5%	a: NS, b: NS, axb: NS					a: NS, b: NS, axb: 3.80				

Table 6: Effect of foliar application of $FeSO_4$ and potassium humate on accumulation of N, P and K% in herb and seeds of coriander plants at two seasons

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
N herb (%)										
0	1.27	1.23	1.38	1.60	1.37	1.29	1.39	1.61	1.62	1.48
1	1.41	1.38	1.49	1.63	1.48	1.29	1.40	1.60	1.57	1.47
2	1.35	1.41	1.57	1.61	1.49	1.51	1.42	1.58	1.66	1.54
3	1.44	1.60	1.57	1.70	1.58	1.57	1.58	1.70	1.74	1.65
Mean	1.37	1.41	1.50	1.64		1.42	1.45	1.62	1.65	
LSD 5%	a: 0.14, b: NS, axb: NS					a: 0.12, b: 0.12, axb: 0.23				
N seeds (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	1.72	1.88	2.19	2.00	1.94	1.87	2.10	2.41	2.64	2.25
1	1.95	2.11	2.19	2.26	2.12	2.06	2.38	2.64	2.73	2.45
2	2.14	2.09	2.57	2.78	2.39	2.43	2.46	2.65	2.73	2.56
3	2.14	2.49	2.86	2.88	2.59	2.68	2.73	2.75	2.86	2.75
Mean	1.98	2.14	2.45	2.48		2.23	2.42	2.61	2.73	
LSD 5%	a: 0.13, b: 0.10, axb: 0.30					a: 0.10, b: 0.10, axb: 0.30				
P herb (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	0.24	0.27	0.29	0.31	0.28	0.25	0.26	0.28	0.28	0.27
1	0.27	0.37	0.38	0.39	0.35	0.26	0.30	0.32	0.34	0.31
2	0.31	0.34	0.34	0.36	0.34	0.28	0.28	0.28	0.31	0.29
3	0.28	0.31	0.34	0.33	0.33	0.27	0.27	0.27	0.29	0.28
Mean	0.28	0.33	0.34	0.35		0.27	0.28	0.29	0.31	
LSD 5%	a: 0.03, b: NS, axb: NS					a: 0.03, b: NS, axb: NS				
P seeds (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	0.37	0.37	0.39	0.40	0.39	0.36	0.37	0.38	0.38	0.38
1	0.37	0.41	0.49	0.50	0.46	0.40	0.40	0.48	0.48	0.44
2	0.39	0.40	0.47	0.48	0.43	0.40	0.40	0.40	0.50	0.42
3	0.38	0.38	0.42	0.41	0.39	0.37	0.38	0.40	0.40	0.41
Mean	0.37	0.41	0.44	0.45		0.38	0.41	0.42	0.47	
LSD 5%	a: 0.23, b: 0.25, axb: 0.55					a: 0.27, b: 0.29, axb: 0.57				
K herb (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	1.13	1.15	1.22	1.26	1.19	1.20	1.35	1.53	1.56	1.41
1	1.18	1.29	1.6	1.71	1.45	1.52	1.60	1.66	1.69	1.62
2	1.16	1.24	1.59	1.72	1.43	1.47	1.53	1.62	1.67	1.57
3	1.14	1.16	1.22	1.64	1.29	1.30	1.50	1.59	1.62	1.51
Mean	1.15	1.21	1.41	1.58		1.37	1.50	1.60	1.64	
LSD 5%	a: NS, b: NS, axb: NS					a: NS, b: NS, axb: 0.18				
K seeds (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	0.90	1.33	1.43	1.47	1.28	1.02	1.12	1.30	1.22	1.16
1	1.40	1.51	1.55	1.65	1.52	1.35	1.42	1.49	1.48	1.43
2	1.23	1.38	1.47	1.70	1.44	1.19	1.29	1.39	1.58	1.36
3	1.04	1.33	1.43	1.54	1.33	1.09	1.19	1.37	1.43	1.27
Mean	1.17	1.38	1.47	1.53		1.16	1.25	1.39	1.46	
LSD 5%	a: 0.18, b: 0.13, axb: 0.28					a: 0.14, b: 0.12, axb: 0.27				

Table 7: Effect of foliar application of $FeSO_4$ and potassium humate on accumulation of Fe in leaves and seeds (ppm) of coriander plants at two seasons

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
Fe (ppm) in leaves										
0	40.90	40.50	42.80	43.90	42.03	40.90	41.30	44.10	45.60	42.98
1	41.20	41.90	44.48	46.70	43.57	41.70	42.10	45.40	45.80	43.75

Table 7: Continue

	Humic									
	1st season					2nd season				
Iron (Fe) (%)	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
2	42.30	42.10	46.40	47.70	44.63	42.60	43.80	46.60	45.50	44.63
3	42.90	43.90	45.90	48.10	45.20	43.70	44.60	45.40	47.50	45.30
Mean	41.83	42.10	44.90	46.60		42.23	42.95	45.38	46.10	
LSD 5%	a: 1.39, b: 1.16, axb: 3.11					a: 1.57, b: 1.72, axb: 2.93				
Fe (ppm) in seeds	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean	0 (g L^{-1})	1 (g L^{-1})	2 (g L^{-1})	3 (g L^{-1})	Mean
0	14.56	15.56	16.07	16.67	15.72	14.56	15.73	16.98	17.96	16.31
1	15.17	15.66	17.33	17.82	16.50	15.92	16.92	18.18	19.92	17.74
2	15.27	15.48	17.67	18.56	16.75	16.08	17.33	19.48	19.37	18.07
3	16.73	18.08	19.37	20.01	18.55	17.55	18.82	18.56	20.87	18.95
Mean	15.43	16.20	17.61	18.27		16.03	17.20	18.30	19.53	
LSD 5%	14.56					15.56				

CONCLUSION

The results of this study after two successive years of continues work showed a positive effect of the use of foliar application of ($FeSO_4$) and potassium humate alone or together as fertilizers on the total chlorophyll a, b, carotenoids, nitrogen, potassium and phosphorus a Fe contents and biomass partitioning and ultimately the yield of coriander. Whereas the combination of 2% $FeSO_4$+2 or 3 g L^{-1} potassium humate was the best for overall increasing of essential oil in both seasons and other tested parameters.

SIGNIFICANCE STATEMENTS

This study after two successive years of continues work discovers the possible synergistic and beneficial effect of foliar application of ($FeSO_4$) and potassium humate together as fertilizers on the coriander plants. This study will help the researchers to uncover the critical area of the combinations various fertilizers as foliar applications that many researchers were not able to explore. Thus, a new theory may be reached on these nutrient structures and possibly other combinations.

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