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Moringa leaf extract application as a natural biostimulant improves the volatile oil content, radical scavenging activity and total phenolics of coriander

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Abstract
Recently, using the biostimulants in enhancing the growth and yield of crops is a very pressing topic especially with medicinal plants because of its therapeutic values. Moringa leaf extract (MLE) has gained more consideration among the natural biostimulants but the information about its impact on medicinal plants is scarce. Therefore, the current study is an attempt to bridge the gap. Coriander plants were foliar sprayed with MLE at 50, 100, 200 and 300 g L^{-1} while the untreated plants were sprayed with distilled water. MLE treatment considerably enhanced the growth characters which reflected in improving the fruit yield compared to untreated plants. Importantly, MLE treatment not only increased volatile oil yield of coriander but also enhanced volatile oil components relative to untreated plants. The major volatile oil components i.e. Limonene, ß- Cymene and Linalool were more accumulated by MLE application. Otherwise, the percentages of N, P, K and total sugars were considerably increased due to MLE treatment. Interestingly, the radical scavenging activity and total phenolics were considerably improved with the MLE application relative to untreated plants. Applying MLE at 200 g L^{-1} was the most effective concentration compared to the other levels. Conclusively, using MLE as a promise plant biostimulat may be suggested to improve the productivity and quality of coriander plant.

Keywords: Biostimulants, total sugars, phenolics, radical scavenging, nutrients

1. Introduction

Coriander (*Coriandrum sativum*, L. var. microcarpum) belongs to family *Umbelliferae* (*Apiaceae*) is an imperative medicinal plant that commonly cultivated for volatile oil production.

Coriander is a native plant of the eastern Mediterranean and it may have spread to several countries like India, China and rest of the world (Coskuner and Karababa, 2007) [12]. Coriander is commonly used to mask unpleasant odors of certain foods or as food flavouring (Potter, 1996) [31]. Additionally, it used to suppress offensive odors in pharmaceutical preparations as an antispasmodic, stimulant, carminative and stomachic (Gil *et al*., 2002) [15]. Because of the great interest of coriander volatile oil, more studies are still required for improving its growth and productivity. Because of the progressive reduction in the production land in the last decades, there is a challenge to increase the productivity of medicinal plants at the same cultivated area (Pandey and Patra, 2015) [27].

The common application that has been used for increasing the productivity is chemical fertilization. However, the intensive use of chemical fertilizers causes soil degradation, environmental pollution and increases the production costs (Phiri, 2010; Hassan *et al*., 2012) [28, 29, 18]. Economically, the excessive use of chemical fertilizers limits the export of such crops (Hassan and Ali, 2013) [17]. Therefore, searching about alternative sources that can naturally improve the productivity of such plants has been become the main interest of several scientists worldwide for achieving the agriculture sustainability (Abdalla, 2013) [1]. Recently, there are several natural biostimulant used for improving the growth and productivity of different crops. Among them, moringa leaf extract (MLE) obtained from moringa (*Moringa oleifera*, Lam) engaged more attention (Hassan and Fetouh, 2019) [19]. MLE is considered one of the most natural biostimulants that may be applied as an environmentally friendly alternative source of chemical fertilizers (Phiri and Mbewe, 2010; Abdel-Rahman and Abdel-Kader, 2019) [28, 29, 2]. The most important contents of MLE are amino acids, phenolics, carotenoids, flavonoid, macro and micro-nutrients, ascorbic acid, zeatin, vitamins A and C (Latif and Mohamed, 2016; Hassan and Fetouh, 2019) [22, 19]. Application of MLE as biostimulant resulted in higher economic return in several agronomy crops due to improving the productivity whether applied in non-stressed conditions (Ashraf *et al*., 2016; Nasir, *et al*., 2016) [5, 25] or under environmental stress (Yasmeen *et al*., 2013; Latif and Mohamed, 2016) [36, 22]. The growth and leaf productivity of cassava plants were considerably improved by MLE application (Ndubuaku *et al*., 2015) [26]. MLE treatment enhanced the protein and total chlorophyll in spinach leaves compared to some investigated growth regulators (Aslam *et al*., 2016) [6].

The most previous works of MLE were investigated on grain or vegetable crops however; there are few studies about the impact of MLE on medicinal plants including coriander. In this concern, MLE treatment enhanced basil growth and yield (Prabhu *et al*., 2010) [32], geranium (Hassan and Fetouh, 2019) [19] and fennel (Abdel-Rahman and Abdel-Kader, 2019) [2]. Interestingly, the impact of biostimulants including MLE has not been investigated yet on coriander although the economic and pharmaceutical importance of volatile oil of coriander. To our knowledge, the response of coriander plant to MLE application is not well affirmed. Hence, the current investigation was carried out to study the influence of MLE on coriander growth, fruit yield, and volatile oil content. Additionally, the effects of MLE on nutrient content, total soluble sugars, total phenolics, radical scavenging activity were also assessed.

2. Materials and Methods

2.1 Plant materials

Two field experiments were conducted at Faculty of Agriculture, Menoufia University, Shibin El-Kom (30°33′24.8″N 31°00′51.3″E) during 2015/ 2016 and 2016/2017 seasons. The weather conditions during the experimental period were presented in Table (1). The experimental soil was prepared and divided to 1.8 x 1.8 m plots that contained three rows with 6 hills each (53332 plants/ha). In the first of November in both seasons, the seeds were sown. After three weeks, coriander plants were thinned out to remain one plant per hill. The physical properties of used soil were (15.19% sand, 40.33 silt, 44.48 clay). The soil chemical properties were (pH, 8.06, OM, 0.16%, Total $CaCO_3$, 1.24, EC, 1.31 dsm^{-1}, Na^+, 2.22 ($meqL^{-1}$), SO_4^{-2}, 44.52 ($meqL^{-1}$), Ca^{+2}, 42.17 ($meqL^{-1}$), Cl^-, 0.47 ($meqL^{-1}$), HCO_3, 2.08 ($meqL^{-1}$), total N^+, PO_4^{-3}, K^+ were 0.17, 0.035 and 0.038%, respectively).

2.2 MLE preparation and application

MLE was extracted according to Rady and Mohamed (2015) [33]. The fresh leaves of *Moringa oleifera* were harvested and air-dried then grinded to fine powder. Ethyl alcohol was added to the powder to prepare four concentrations by mixing 50, 100, 200 and 300 g L^{-1} (based on fresh weight) and then the mixture was put on a shaker for 4 h for extraction preparation. MLE obtained was purified using filtering twice through filter paper (Whatman No. 1). MLE was subjected to a rotary evaporator and the extract was centrifuged at 8000 × g for 15 min for alcohol evaporation. Finally, the supernatant obtained from each concentration was diluted to 30 times using distilled water. A surfactant of 0.1% (v/v) Tween-20 was added to MLE and then was foliar sprayed onto coriander plants. The spraying was repeated every 2 weeks till flowering stage. Control plants were water sprayed. The experimental design was a complete randomized design (CRD) with four replicates.

Table 1: Weather conditions of the experimental area during the period of the study in 2015/2016 and 2016/2017 seasons.

Months	Rain level (mm)	Average of air temperature in °C			Soil temperature at 10 cm depth in °C	R.H.%		
		Max	Min	Average		Max	Min	Average
		1st season						
10/2015	8.0	29.79	21.36	25.58	26.19	81.97	22.42	51.19
11/2015	-	29.62	18.84	21.73	22.78	82.77	22.80	52.78
12/2015	-	18.31	11.58	14.94	18.46	83.32	22.61	52.96
1/2016	6.0	16.16	7.79	11.97	15.50	83.26	23.33	53.29
2/2016	14.0	22.61	13.63	18.12	13.87	87.10	29.00	58.05
3/2016	19.5	26.69	16.95	21.64	19.16	84.15	25.00	54.57
4/2016	28.3	28.11	16.01	22.06	21.92	84.63	24.77	54.70
5/2016	-	32.37	19.63	26.00	26.50	84.03	24.71	54.37
		2nd season						
10/2016	-	30.56	20.52	25.54	27.64	82.73	38.83	60.78
11/2016	8.00	23.72	17.16	20.44	23.28	85.23	26.03	55.63
12/2016	-	19.53	12.57	16.05	17.47	83.55	21.53	52.54
1/2017	12.00	15.10	8.32	11.71	16.52	84.52	22.97	53.79
2/2017	15.00	23.71	14.62	19.16	14.12	86.97	28.23	57.60
3/2017	17.00	27.35	16.83	22.09	18.95	85.00	24.87	54.93
4/2017	20.00	29.51	15.53	22.52	22.13	85.10	25.12	55.11
5/2017	-	33.21	20.41	26.81	27.30	84.00	24.97	54.48

2.3 Growth characters and fruit yield

At the 15th of April the plants were harvested in both experimental seasons when fruits were greenish yellow in color and before fully ripening stage. The growth parameters i.e. plant height (cm), branch number (Main branches), herb fresh and dry weight/plant (g) were evaluated. The yield components i.e. number of umbels/plant, fruit yield/plant (g) and per ha (kg) and 100 seed weight (g) were assessed.

2.4 Volatile oil content assessment

Dry fruit samples (50 g) were used for volatile oil percentage determination. The fruits were dried until the weight of the sample remains constant. Hydro-distillation was used for volatile oil extraction in a Clevenger apparatus for 3h. The seeds were milled before distillation. The distillation was done in triplicate samples and the given oil contents are the average values. The oil percentage was determined as described in British Pharmacopea (1963) [11], using the

following equation:
Volatile oil percentage = oil volume in the graduated tube/weight of sample x 100.
Then, the oil yield (plant & ha) were calculated. Anhydrous sodium sulfate was used for volatile oil drying then the oil was stored in dark and cool conditions till GC-MS analysis. Samples of essential oil were performed using a Hewlett-Packard 5890 A series 11 instrument equipped with flame ionization detector (FID) and a carbon wax fused silica column (50 m x 0.25 mm. i. d., film thickness 0.32 µm). Oven temperature was programmed from 60 to 200 ºC, respectively. Volatile oil sample of 1 µL (spilt ratio 1:30) was manually injected. Percentages of peak area were calculated with a Hewlett–Packard 3396 integrator. The oil components were identified by comparing the mass spectrum and retention times with those of standards, NIST library of the GC-MS system and literature data.

2.5 Nutrient elements investigation
Coriander herb samples were oven dried at 70 ˚C for 48 hours. Then, samples were milled to prepare suitable material for nutrient analysis. Samples (0.5 g) were processed by sulphuric and perchloric acids method (Piper, 1967; Jackson, 1978) [30] for mineral content analysis. The micro-Kjeldhl method was used for Nitrogen determination according to Black *et al*. (1965) [9], phosphorus were colorimetrically assessed using the stannous chloride phosphomolibdic-sulforic acid system and measured at 660 nm as described by Jackson (1978) [21], while flame photometer was used for potassium measurement (Jackson, 1979) [20].

2.6 Total soluble sugars determination
The total soluble sugars were assessed using anthrone reagent according to Yemm and Willis (1954). Briefly, dried fruit powder (0.5 g) was homogenized with 10 mL methanol (80%) then centrifuged for 10 min at 3000 rpm. The obtained supernatant was saved while the same volume of the solvent was used for pellet re-extraction. To remove the chlorophyll, the pooled supernatant was partitioned with an equal volume of petroleum ether. From the sides of the test tube, 4 mL of anthrone reagent was added to 1 mL of the above extract and boiled for 10 min in a water bath. Then, the mixture was cooled down to room temperature. For preparing the blank, 1 mL of distilled water in place of the sample was used as reference. The optical density was investigated at 625 nm using spectrophotometer and the soluble sugar was measured using the standard of glucose.

2.7 Total phenol content assay
The total phenol content in fruits was assayed according to McDonald *et al*. (2001) [23]. Briefly, powder samples (1 g) were stirred in 50 mL methanol (80%) by a blender and macerated for two days. After removing the solvent, the extract was kept below 4˚C. The diluted extract (0.5 mL of 1:10 g mL^{-1}) or standard phenolic compound (Gallic acid) was mixed with the Folin-Ciocalteu reagent (5 mL, 1:10 diluted with distilled water) and aqueous Na_2CO_3 (4 mL, 1 M). The total phenol content was spectrophotometrically evaluated at 765 nm and recorded as gallic acid equivalent per gram of fruit extract (mg GAE g^{-1}DW).

2.8 Antioxidant activity (DPPH Assay)
Free radical scavenging activity was determined as described by Brand-Williams *et al*. (1995) [10] using the reagent of 1.1-diphenyl-2-picryl-hydrazil (DPPH). The extracts of fruit samples were soluble in aqueous methanol (85%). Then, 1.5 mL of freshly prepared methanolic DPPH solution (20 µg mL) was added to 0.5 mL of the extract samples in dark and stirred. After 5 min of reaction, the decolorizing processes was recorded at 517 nm and compared with a blank control. The DPPH was expressed as the inhibition percentage (I%) by the following equation:

$$I (\%) = 100 \times (A_{blank} - A_{sample}) / A_{blank}$$

Where: A_{blank} is the control absorbance at 30 min reaction, and A_{sample} is the sample absorbance at 30 min. The extract concentration generating 50% inhibition was considered as antiradical activity (IC_{50}).

2.9 Statistical analysis
The obtained data of each season was subjected to the analysis of variance (ANOVA) using SPSS 13.3 program. Statistical differences were assessed by Tukey-Kramer's multiple range test at $P \leq 0.05$ probability level.

3. Results
3.1 Growth characters
MLE application significantly considerably enhanced the plant height, branch number as well as herb fresh and dry weights at all levels compared to untreated plants (Table 2). All the growth characters were gradually increased with increasing MLE level however increasing MLE concentration from 200 to 300 g L^{-1} did not add any impact on the growth attributes in both seasons since there were no significant ($P \leq 0.05$) differences between them in this respect. Generally, applying MLE at 200 g L^{-1} resulted in the tallest plants with higher branch number and heaviest weight relative to the other levels.

3.2 Fruit yield components
It is very clear from the results of this study that MLE application significantly increased the number of umbels per plant, fruit yield/ plant and ha as well as the weight of 100 seeds in the two experimental seasons compared to untreated plants (Table 3). A gradual increase was observed in fruit yield with increasing MLE level from 50 till 200 g L^{-1} resulted but the highest MLE level (300 g L^{-1}) had no significant improvement compared to 200 g L^{-1} concentration in both seasons. Applying MLE at 200 g L^{-1} enhanced coriander fruit yield/ha by 37.05 and 36.08% over the control in both seasons, respectively.

3.3 Volatile oil content
The volatile oil percentage in coriander fruits and volatile oil yield were significantly increased by MLE traetment compared to untreated plants. The highest percentage and yield of coriander volatile oil were observed when MLE at 200 g L^{-1} was applied without significant difference with 300 g L^{-1} level in both seasons (Table 4). The volatile oil yield/ha was increased by 138.30 and 129.97% over the control when foliar application of MLE at 200 g L^{-1} was applied in both seasons, respectively.

3.4 Volatile oil composition
Foliar application with MLE not only improved the volatile oil yield but also enhanced the volatile oil constituent in coriander fruits. The results of GC-MS indicate that the main constituents of volatile oil were Limonene, ß- Cymene and Linalool. Otherwise, α-pinene, Nerol, Borneol and Geraniol

were also detected (Table 5). Generally, higher MLE concentrations were superior to lower ones in most cases.

Table 2: Effects of moringa leaf extract (MLE) on vegetative growth characters of coriander during the two experimental seasons.

MLE (g L^{-1})	Plant height (cm)	Branch number	Herb FW (g)	Herb DW (g)
2015/2016 season				
Control	65.75 d	6.38 b	39.25 d	10.86 d
50	67.28 c	6.76 b	41.56 c	11.46 c
100	72.33 b	8.18 a	44.18 b	13.48 b
200	74.92 a	8.74 a	48.27 a	13.95 a
300	73.86 ab	8.60 a	47.63 a	13.76 a
2016/2017 season				
Control	68.77 d	5.36 c	40.57 d	10.74 d
50	70.18 c	5.88 c	42.17 c	11.96 c
100	72.48 b	7.57 b	46.27 b	13.24 b
200	74.81 a	8.95 a	48.53 a	13.94 a
300	74.15 a	8.64 a	48.22 a	13.78 a

Means had different letters are significantly differ from each other according to Tukey-Kramer's multiple range test at 5% ($P \leq 0.05$).

Table 3: Effects of moringa leaf extract (MLE) on fruit yield components of coriander during the two experimental seasons.

MLE (g L^{-1})	Number of umbels/plant	Fruit yield (g/plant)	Fruit yield (kg/ha)	Weight of 100 seeds (g)
2015/2016 season				
Control	71.45 d	26.18 d	1396.25d	0.81c
50	74.36 c	28.68 c	1529.58c	0.85 c
100	77.55 b	31.57 b	1683.72b	1.07 b
200	83.49 a	35.88 a	1913.58a	1.22 a
300	82.59 a	35.17a	1875.71a	1.17 a
2016/2017 season				
Control	73.00 b	25.19 d	1343.45d	0.84 c
50	74.00 b	27.68 c	1476.25c	0.86 c
100	77.66 a	30.11 b	1605.85b	1.04 b
200	79.66 a	34.28 a	1828.25a	1.23 a
300	80.33 a	34.17 a	1822.38a	1.21 a

Means had different letters are significantly differ from each other according to Tukey-Kramer's multiple range test at 5% ($P \leq 0.05$).

Table 4: Effects of moringa leaf extract (MLE) on essential oil content of coriander during the two experimental seasons.

MLE (g L^{-1})	Volatile oil (%)	Oil yield (mL/plant)	Oil yield (L/ha)	Volatile oil (%)	Oil yield (mL/plant)	Oil yield (L/ha)
	2015/2016 season			2016/2017 season		
Control	1.34d	0.35d	18.71d	1.29d	0.32d	17.33d
50	1.56c	0.45c	23.86c	1.46c	0.40c	21.55c
100	1.93b	0.61b	32.50b	1.82b	0.55b	29.23b
200	2.33a	0.84a	44.59a	2.18a	0.75a	39.86a
300	2.29a	0.81a	42.95a	2.11a	0.72a	38.45a

Means had different letters are significantly differ from each other according to Tukey-Kramer's multiple range test at 5% ($P \leq 0.05$).

Table 5: Effects of moringa leaf extract (MLE) on the main components of coriander fruit volatile oil during the two experimental seasons.

Main components	Component (%)				
	MLE (g L^{-1})				
	Control	50	100	200	300
α-pinene	2.34	2.45	2.47	3.14	3.22
Limonene	17.54	17.98	18.24	18.46	18.57
ß- Cymene	24.87	24.48	24.88	25.33	25.18
Linalool	36.54	36.57	37.58	37.88	37.46
Nerol	6.21	6.78	7.24	7.55	7.49
Borneol	1.88	2.12	2.22	1.87	2.13
Geraniol	1.89	2.19	1.88	2.22	2.12

3.5 Nutrient elements
Data in Table (6) clearly indicate that the nutrient contents of coriander herb (i.e. N, P and K) were significantly ($P \leq 0.05$) increased by MLE treatment. Generally, the increase in MLE concentration, the increase in nutrient elements content in coriander however, increasing the highest MLE level had no more impact in this concern. The highest N, P and K percentages were observed when 200 or 300 g L^{-1} MLE levels was applied without significant differences. On the other hand, the lowest percentages of N, P and K were observed in untreated plants.

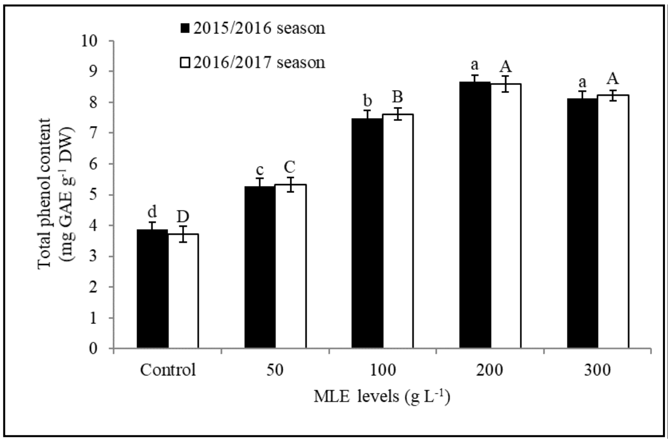
3.6 Total soluble sugars
All MLE applied levels considerably increased the total soluble sugars of coriander plants relative to the control (Table 6). A significant and gradual increase was observed by increasing MLE concentration till 200 g L^{-1} that maximized the total soluble sugars since the level 300 g L^{-1} had no a significant impact relative to 200 g L^{-1} in both seasons. The lowest total sugars were observed in control plants. Relative to the control, applying MLE at 200 g L^{-1} in increased the total sugars by 56.29 and 66.33% in both seasons, respectively.

Table 6: Effects of moringa leaf extract (MLE) on the chemical composition of coriander herb during the two experimental seasons.

MLE (g L^{-1})	Elements (%)			Carbohydrates (%)	Elements (%)			Carbohydrates (%)
	N	P	K		N	P	K	
	2015/2016 season				2016/2017 season			
Control	1.91 d	0.21 c	1.43 c	9.45 d	1.88 d	0.22 b	1.42 c	9.12 d
50	1.98 c	0.22 c	1.47 c	11.67 c	1.96 c	0.23 b	1.45 c	11.57 c
100	2.18 b	0.27 b	1.56 b	13.51 b	2.19 b	0.29 a	1.59 b	13.48 b
200	2.37 a	0.58 a	1.68 a	14.77 a	2.35 a	0.28 a	1.70 a	15.17 a
300	2.25 a	0.59 a	1.64 a	14.38 a	2.34 a	0.29 a	1.69 a	15.22 a

Means had different letters are significantly differ from each other according to Tukey-Kramer's multiple range test at 5% ($P \leq 0.05$).

3.7 Total phenol content
The range of total phenol content of coriander fruits due to MLE application was 3.72 to 8.67 mg GAE g^{-1} DW (Fig. 1A). All MLE levels considerably enhanced the total phenolics compared to the control. Higher MLE levels increased the total phenolics rather than lower ones. More profound impact of MLE was recorded at 200 g L^{-1} in both seasons, however using the highest MLE level (300 g L^{-1}) had no more impact compared with 200 g L^{-1} level. Fruit samples obtained from untreated plants recorded the lowest phenolic content.



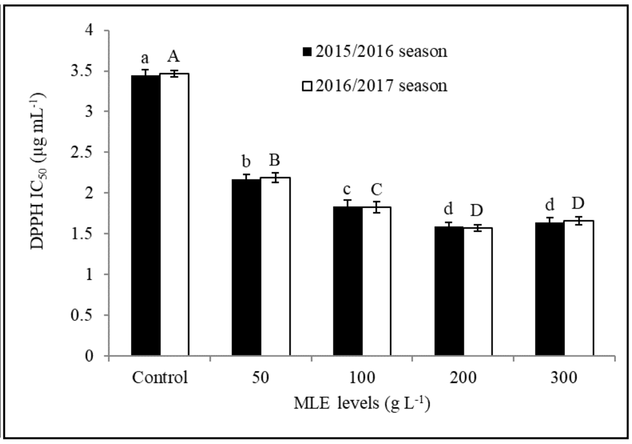


Fig 1: Total phenol content (A) and antioxidant activity as DPPH (B) of coriander fruits treated with moringa leaf extract (MLE)**.** DPPH IC_{50} is the antioxidant amount required to inhibit DPPH radical by 50%. Bars are means ± SE and n = (3). Columns had different letters in each season are significantly differ from each other according to Tukey-Kramer's multiple range test at 5% ($P \leq 0.05$).

3.8 Antioxidant activity
The results of this experiment show also that MLE treatment significantly ($P \leq 0.05$) enhanced the radical scavenging capacity of coriander fruits relative to the control (Fig. 1B). Increasing the MLE level resulted in a gradual decrease in IC_{50} value. The optimum MLE concentration was 200 followed by 300 g L^{-1} without significant difference between them. The lowest IC_{50} value was observed when MLE at 300 g L^{-1} was applied which lowered the IC_{50} by 46.08 and 45.24% relative to the control in both seasons, respectively.

4. Discussion
Recently, the main goal of several researches is enhancing the growth and production of medicinal plants via natural biostimulants. It has been observed that MLE as a biostimulant enhanced the vegetative growth that reflected in increasing the yield of several crops (Ndubuaku *et al*., 2015; Ashraf *et al*., 2016; Abdel-Rahman and Abdel-Kader, 2019) [26, 5, 2]. MLE has found to be rich in nutrient elements, amino acids, antioxidants, and phytohormones (Ali *et al*., 2018; Hassan and Fetouh, 2019) [4, 19]. Moreover, jasmonic acid and salicylic acid are also detected in MLE (Elzaawely *et al*., 2016) [13] and therefore MLE is considered an excellent growth enhancer that improves the coriander growth in current study.
Enhancing the coriander growth by MLE treatment could be explained through the presence of cytokinins especially zeatin in MLE (Yasmeen *et al*., 2013; Elzaawely *et al*., 2016) [36, 13] which promotes cell division and elongation and consequently improves the plant growth (Nagar *et al*., 2006) [24]. Additionally, the observed auxins and giberellins in MLE (Ali *et al*., 2018) [4] can enhance the cell elongation and promote the cell division (Taiz and Zeiger, 2010) [35]. Enhancing the coriander growth by MLE application in this study agrees with Hamad and El-Basuony (2017) [16] on dill, Ali *et al*. (2018) [4] on geranium and Abdel-Rahman and Abdel-Kader (2019) [2] on fennel.
In current study, MLE application enhanced the fruit yield of coriander. Increasing the fruit yield could be ascribed to the improvement in coriander vegetative growth due to MLE treatment as our data indicated (Table 1). The current findings support the previous results in fennel (Abou-Sreea and Matter, 2016) [3], dill (Hamad and El-Basuony, 2017) [16] and geranium (Ali *et al*., 2018) [4]. Moreover, Abdel-Rahman and Abdel-Kader (2019) [2] explained the increase in fennel fruit yield due to MLE treatment through the stimulation effects of MLE on photosynthates and their assimilation that motivate plants to produce higher fruit yield.
Interestingly, MLE treatment not only increased the coriander fruit yield but also improved the fruits volatile oil suggesting that MLE could be a promise plant growth promoter that improved the content of volatile oil in coriander. MLE application also positively affected the volatile oil constituents (Table 4). Increasing the volatile oil in coriander by MLE could be due to the MLE components including amino acids, nutrient elements and phytohoromes that motivate the accumulation of secondary metabolites (Ali *et al*., 2018) [4]. The phytohormones affect the pathway of terpenoids through motivating the responsible physiological and biochemical processes (Bano *et al*., 2016) [8]. Our results

are in agreement with the reports of Ali *et al*. (2018) [4] in geranium and Abdel-Rahman and Abdel-Kader (2019) [2] in fennel who observed that MLE application improves both the volatile oil yield and its components.

Phenolics accumulation in medicinal plants has acquired much attention because of their properties of disease preventing and health promoting (Ashraf *et al*., 2016) [5]. The current results depict that MLE application improved the total phenolics in coriander fruits compared to the control (Fig. 1A). The higher phenolic content in plants treated with MLE could be attributed to the higher concentrations of flavonoids, phenolics and phytohormones detected in MLE that contribute to the enhanced phenolic content (Aslam *et al*., 2016) [6]. Additionally, the vitamins and β-carotene found in MLE affect the metabolic processes in such a way that it improved the internal phenolic content in coriander fruits (Aslam *et al*., 2014) [7]. For this reason, MLE has found to be natural antioxidant and plant growth enhancer (Singh *et al*., 2009). Increasing the total phenolics due to MLE application has been previously observed in mandarin (Nasir *et al*. (2016) [25], geranium (Ali *et al*., 2018) [4] and gladiolus (Hassan and Fetouh, 2019) [19].

Evaluating the DPPH is a reliable assay for the assessment of antioxidant potency because it deals with free radical scavenging. In this study, MLE treatment considerably enhanced the scavenging activity in coriander relative to untreated plants. The observed values of IC_{50} were lower in MLE treated plants compared to the control (Fig. 1B). In this regard, Aslam *et al*. (2014) [7] reported that MLE improved the DPPH scavenging potential in coriander. Otherwise, MLE has found to be superior radical scavenger compared with other hormones (Ashraf *et al*., 2016) [5] in radish and (Aslam *et al*., 2016) [6] in spinach. In the same direction, Ali *et al*. (2018) [4] revealed that MLE application increased the capacity of radical scavenging in geranium.

In current investigation, foliar application with MLE enhanced the percentages of N, P and K in coriander. This increment could be explained through the fact that MLE is rich in minerals (Ali *et al*., 2018) [4] and its application therefore increases the mineral uptake. Our results are in accordance with the findings of Abdalla (2013) [1] in rocket, Nasir *et al*. (2016) [25] in mandarin and Ali *et al*. (2018) [4] in geranium who observed a considerable increase in minerals as a result of MLE treatment. The soluble sugars in coriander herb were appreciably improved due to MLE treatment. Higher content of sugars found in moringa leaves may play a vital role in sugar accumulation in coriander herb. Enhancing the photosynthetic pigments as a result of MLE treatment may be explaining such effect (Abou-Sreea and Matter, 2016) [3]. Additionally, the cytokinins that detected in MLE might motivate the carbohydrate metabolism (Emongor, 2015) [14]. In this regard, Latif and Mohamed (2016) [22] in common bean, Ali *et al*. (2018) [4] and Abdel-Rahman and Abdel-Kader (2019) [2] in fennel observed a considerable increase in soluble sugars due to MLE application.

5. Conclusion

Foliar application with MLE enhanced the growth and fruit yield of coriander. Both volatile oil content and components were also improved in MLE treated plants. Importantly, MLE treatment improved the total phenolics and radical scavenging activity in coriander fruits which is very important factor in disease preventing. The mineral and soluble sugars contents in coriander herb were also enhanced by MLE treatment. MLE application as a promise plant growth enhancer may be suggested to maximize the productivity and quality of coriander fruits via biostimulants. Using MLE as safe, cheap and ecofriendly plant growth stimulator has been suggested to achieve the agriculture sustainability and safe production of medicinal and aromatic plants.

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7. References

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