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The effects of soil cover and Stimplex (*Ascophyllum nodosum* extract) foliar application on antioxidant activity and some physiological characteristics of *Coriandrum sativum* L.

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Abstract

Two field experiments were conducted as factorial based on randomized complete block design to study the effects of soil covering (black, white, control), location (Sarab and Shabestr, Iran), and Stimplex foliar application levels (0, 2, 4 and 6 ml L^{-1}) on growth and physiological traits of *Coriandrum sativum*. The highest values for essential oil, flavonoids and nitrogen contents were recorded for black covering at 2 ml L^{-1} foliar application of Stimplex. For phenolic compounds the highest values were observed with black covering at 2, 4 and 6 ml L^{-1} of foliar spray. In the city of Sarab, maximum values of root dry weight and essential oil content were obtained with 6 and 2 ml L^{-1} Stimplex spray, respectively. The best IC_{50} belonged to the white and black soil covers in Shabestar (1.6 and 1.7 mg ml^{-1}, respectively). Foliar spray had significant effects on the above-ground biomass, plant height, axillary brunch number, umbel number, total soluble solids (TSS), phosphorus and potassium contents. Sarab had higher values than Shabestar for the nitrogen and potassium contents, axillary brunch number and TSS. Black soil cover had positive effects on K (%), P (%), TSS, chlorophyll a, umbel number per plant, plant height, axillary brunch number and above-ground biomass. In total, the results revealed that using black soil cover and foliar application of algal extract (2 ml.L^{-1}) improved the growth and physiological responses of *C. sativum* plants.

Keywords: Coriander; Essential oil; Growth; IC_{50}; Phenolic content; Yield

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Introduction

Coriander (*Coriandrum sativum* L.) is an annual and herbaceous species of Apiaceae family (Small 1997). Coriander is cultivated for its aromatic leaves and seeds (Sharma and Sharma 2012). Coriander oil is rich in linalool, γ-terpinene and geranyl acetate (Bhuiyan *et al.* 2009) plus other compounds such as limonene, α-pinene and linalyl acetate (Rastogi and Mehrotra 1993) and camphene (Telci *et al*. 2006). The oil is greatly used as a flavoring agent in the food industry (Bhuiyan *et al.* 2009), protects the food from spoiling microorganisms, has a role in the preservation of food products (Silva and Domingues 2015), as well as in beverages (Mandal and Mandal 2015) and pharmaceutical industries (Chopra *et al*. 1956). Coriander is recommended because of its anti-rheumatic (Rajeshwari and Andulla 2011), anti-inflammatory (Ammar *et al*. 1997) and antibacterial and antifungal properties (Kalemba and Kunicka 2003). Fresh leaves and dried seeds of *C. sativum* plant are edible. *C. sativum* contains proteins, vitamins, minerals, fibers and carbohydrates (Nadeem *et al*. 2014).

Reports have shown that bio-fertilizers improve plant growth by supplying nutrients to plant and may contribute to healthy environment as compared to synthetic fertilizers (O'Connell 1992). The absorption of nutrients sprayed on the foliage are generally more rapid and efficient than when applied to the soil. Stimplex [extracted from *Ascophyllum nodosum* which includes mineral elements (N, P, K, Fe, Zn, Mg), vitamins, kinetin and carbohydrates] is one regarded as an important biological fertilizer which is used as foliar application. Vojodi Mehrabani *et al*. (2016) showed that organic manure and soil cover increased plant dry weight and growth of *Calendula officinalis*. The beneficial effects of seaweed extract foliar application were demonstrated on *Phaseolus vulgaris* (shoot length and root length) by Latique *et al.* (2013), on corn (1000 seed weight, stem weight, kernel number per row, ear diameter) by Partani (2013) and on Dutch fennel plants by Wafaa *et al.* (2017).

Conserving natural resources, soil and water, is a universal goal of sustainable and organic agriculture. In developing countries such as Iran, the crop production potential is limited mainly due to water scarcity and uneven precipitation distribution. In arid and semi-arid agricultural systems, soil cover is a proposed solution for the optimum water consumption (Qin *et al.* 2015). Soil mulching management techniques can reduce evaporation, soil erosion (Doring *et al*. 2005), may adjust soil temperature (Lal 1974), decrease weed density, improve yields and also water and nutrients use efficiency (Sinkeviciene *et al.* 2009; Fan *et al.* 2012). Sinkeviciene *et al.* (2009) reported that organic mulches (peat and sawdust) significantly decreased soil temperature and increased soil moisture. Qin *et al.* (2015) indicated that plastic soil covers had significant effect on increasing maize yield compared to straw mulch due to the reduction of soil temperature and the potential of N fixation in soil. Fan *et al.* (2012) reported that plastic mulch increased total fruit weights of strawberry. They stated that elevated soil temperature under cover might affect the establishment and growth of strawberry plants and promote their yield.

Nowadays, the need for the production of medicinal and spice plants with high antioxidant potential has increased due to increase in the world population. There is not sufficient information on the effects of bio-organic fertilizers, such as Stimplex, on *C. sativum*. Therefore, the aim of this study was to evaluate the effects of Stimplex foliar application and soil cover on the plant growth and some physiological characteristics as well as antioxidant activity of *C. sativum* grown at Sarab and Shabestar areas in Iran.

Material and Methods

This work was conducted at two different localities of Sarab (longitude: 47º32′10″ E; latitude: 37º56′29″ N) and Shabestar (latitude: 45º59′30″ E; longitude: 38º21′30″ N), East Azarbijan Province, Iran. Seeds of a landrace of *C. sativum* from Isfahan, Iran were planted in 1.5 × 1.5 m plots. Soil characteristic are presented in Table 1. White and black polyethylene were used as soil cover in the treated plots plus a control without the soil cover. The plants were treated with Stimplex (*Ascophyllum nodosum*) (Canada; ordered by Arman Sabz Adineh Company, Iran) 35 days after planting, at four levels: 0, 2, 4 and 6 mlL^{-1}. The active ingredients of Stimplex are included in Table 2. Stimplex solution for the treatments was freshly prepared before spraying. Stimplex was applied for the second time 15 days after the first spray. After two weeks, the herbage was harvested by cutting over the soil surface and then above ground biomass, number of umbels per plant, plant height, number of auxiliary branches, essential oil content, N, P and K content, chlorophyll a, b, a/b, total soluble solids, IC_{50} (half maximal inhibitory concentration) as well as total phenolic and flavonoids contents were determined.

Experimental design was factorial based on randomized complete block design with three replications. The data obtained were subjected to standard analysis of variance. Means were compared by Duncan's multiple range test at 5% level of significance.

Table 1. Soil and weather characteristic of the experimental field in Sarab and Shabestar, Iran.

Soil characteristics	Sarab	Shabestar
pH	7.9	7.6
Soil texture	sandy loam	sandy loam
EC	1.5dS m^{-1}	1.99dS m^{-1}
N	5%	4.9%
P	48 mg kg^{-1}	56 mg kg^{-1}
K	300 mg kg^{-1}	297 mg kg^{-1}
Weather		
Maximum temperature	30 ºC	39 ºC
Minimum temperature	15 ºC	25 ºC

Table 2. Active ingredient of Stimplex (*Ascophyllum nodosum*) used as the crop bio-stimulant.

Ingredient	%	Other compounds	%
Cytokinin (as kinetin)	0.01	Magnesium	0.1
Total nitrogen	0.1	Boron	16
Phosphoric acid	0.05	Calcium	0.06
Soluble potassium	4.2	Amino acids	Not mentioned
Iron	25	Biostimulants	Not mentioned

Total chlorophyll content

Chlorophylls content was determined in acetone extract according to Arnon (1949) and Wellburn (1994). The absorbance was read by a spectrophotometer at 663 and 645 nm.

Antioxidant Activity

Antioxidant activity was measured based on the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH). First, 0.5 mM control solution was prepared in methanol. Then, the control solution (1M) was added to 3 ml of different concentrations of each sample. Later, the samples were put in dark at the room temperature for 30 minutes. Absorbance was recorded at 517 nm (Zhang and Hamauzu 2004). Antioxidant compounds were measured at different concentrations to obtain IC_{50}. The DPPH scavenging effect was calculated according to the following formula:

$$\text{DPPH scavenging effect (\%)} = (A_0 - A_1/A_0) \times 100$$

where A_0 is the absorbance of the control and A_1 is the absorbance of test samples.

Antioxidant compounds were evaluated in different concentration of samples to obtain the amount of IC_{50}. IC_{50} is defined as the concentration of antioxidant necessary to decrease the initial DPPH concentration by 50%. IC_{50} of the samples was derived from the plot of % scavenging activity vs. antioxidant concentration and is expressed as mg/ml.

Total phenolics concentration

Total phenolics content (TPC) was determined according to Kim *et al.* (2006) using the Folin-Ciocalteu method. The phenolic content was demonstrated as mg of gallic acid equivalent per gram of dry sample (mg $GAg^{-1}DWt$).

Total soluble solids concentration (°Brix)

The filtered leaf extracted juice was used for the measurement of total soluble solids (TSS) by a digital refractometer (Erma, Tokyo, Japan).

Essential oil extraction

The essential oil was extracted from a 25-g dry plant sample by water distillation for 3 h using a Clevenger-type apparatus and the oils were dried over anhydrous sodium sulphate.

Determination of N, P and K (%)

The concentration of K was determined from the dried ground leaves by a Flame photometer. N was measured by Kjeldahl method and P content was determined by vanadate molybdate according to Emami (1996).

Result and Discussion

Plant Height

Data presented in Table 3 and 4 indicates that Stimplex foliar had significant effects on plant height. Application of Stimplex at 2 and 4 mlL^{-1} increased plant height to 30.6 cm. According to Table 5, black and white soil covers had positive and significant effects on plant height (30.6 and 28.8 cm, respectively) as compared to the control (22.4 cm). Location had significant effect on plant height and the highest value (29.3 cm) was recorded in the city of Sarab (Table 6). Seemingly, the reason for greater height in Sarab was due to low temperature during the growing season which reduced transpiration rate and subsequently, loss of assimilates. In a study conducted by Ni *et al*. (2016) in *Osmanthus fragrans*, plant height and trunk diameter were greatly increased with wood chips and round gravel ground covers. This was probably because of the higher accessibility of water to the plants and available nitrogen in the soil. Vojodi Mehrabani *et al.* (2016) reported the yield improvement in *Calendula officinalis* by the usage of animal manure and bed cover. In another research, Haggag *et al*. (2014) reported that algae extract affected plant height, lateral shoot number, stem diameter, leaf number and root length of olive seedlings. Algae extract contains nutritional elements and cytokine which promote the physiological activities and increase the chlorophyll content in the plant. Improving photosynthesis rate increases the growth potential of plants by partitioning of more assimilates and eventually, leads to increased yield components Abd El Moniem and Abd-Allah 2008; Haggage *et al*. 2014).

Auxiliary branch number

The highest auxiliary branches number (5.4) was

Table 3. Analysis of variance of the effects of Stimplex foliar application, soil cover and location on some growth characteristics of *Coriandrum sativum* L.

Source of variation	df	Root dry weight	Above-ground biomass	Plant height	Auxiliary branch number	Umbel number per plant	Essential oil percent	N content	P content	K content
Location (L)	1	17.8^{ns}	53^{ns}	273^{ns}	6.1	0.6^{ns}	0.007**	0.30**	0.007^{ns}	0.84**
Replication / L	4	13.9**	301**	59*	9.4**	1.7^{ns}	0.0008**	0.04^{ns}	0.007^{ns}	0.22^{ns}
Soil cover (SC)	2	26.3**	211**	445**	20**	6.2*	0.003**	1.4**	0.038**	0.18**
Foliar application (FA)	3	13.5**	280**	571**	12**	6.8**	0.0004^{ns}	3.3**	0.025**	3.8**
SC × FA	6	3.2^{ns}	46^{ns}	40^{ns}	1.2^{ns}	1.6^{ns}	0.001**	0.12*	0.001^{ns}	0.12^{ns}
SC × L	2	9.0*	1.4^{ns}	32^{ns}	0.04^{ns}	1.8^{ns}	0.0004^{ns}	0.02^{ns}	0.002^{ns}	0.01^{ns}
FA × L	3	12.7**	9.2^{ns}	27^{ns}	0.68^{ns}	1.1^{ns}	0.0003*	0.01^{ns}	0.001^{ns}	0.04^{ns}
SC × FA × L	6	2.85^{ns}	13^{ns}	9^{ns}	1.04^{ns}	1.3^{ns}	0.0003^{ns}	0.01^{ns}	0.001^{ns}	0.06^{ns}
Error	44	1.89	22	20	0.70	0.94	0.0002	0.04	0.003	0.10
CV (%)		10.9	8.2	16.2	16.9	13.0	13.1	10.0	18.0	15.0

ns, * and **non-significant and significant at p≤ 0.05 and p≤ 0.01, respectively; whenever the "Replication / L" mean square was not significant, it was pooled with the "Error" term to test the "Location" mean square.

Table 3 continued

Source of variation	df	Chlorophyll b	Chlorophyll a	Chlorophyll a/b	Total phenolics content	Total soluble solids	Total flavonoids content	IC$_{50}$$^{+}$
Location (L)	1	1.1^{ns}	0.003^{ns}	0.09^{ns}	80.0^{ns}	2.1^{ns}	10.7^{ns}	0.74*
Replication / L	4	1.1^{ns}	0.24**	0.06^{ns}	206.2**	1.4**	36.1**	0.16^{ns}
Soil cover (SC)	2	0.69^{ns}	0.61**	0.05^{ns}	4164.3**	2.5**	198**	0.70*
Foliar application (FA)	3	0.18^{ns}	0.05^{ns}	0.11^{ns}	3124**	4.8**	158**	2.40^{ns}
SC × FA	6	1.02^{ns}	0.01^{ns}	0.03^{ns}	160·0**	0.18^{ns}	29·0**	0.17^{ns}
SC × L	2	1.04^{ns}	0.07^{ns}	0.05^{ns}	42.3^{ns}	0.08^{ns}	3.8^{ns}	1.00**
FA × L	3	0.73^{ns}	0.02^{ns}	0.21^{ns}	1.4^{ns}	0.16^{ns}	0.8^{ns}	0.11^{ns}
SC × FA × L	6	0.76^{ns}	0.02^{ns}	0.02^{ns}	13.0^{ns}	0.03^{ns}	5.1^{ns}	0.38^{ns}
Error	44	0.97	0.02	0.09	45.1	0.16	7.4	0.14
CV (%)		18.0	13.0	14.4	10.3	17.3	11.6	18.6

ns,* and **non-significant and significant at p≤ 0.05 and p≤ 0.01, respectively; $^{+}$half maximal inhibitory concentration; whenever the "Replication / L" mean square was not significant, it was pooled with the "Error" term to test the "Location" mean square.

recorded at Sarab (Table 6). Stimplex foliar application in all treatments increased auxiliary branch number and the lowest auxiliary branch number (3.9) was recorded in the control plants (Table 4). Based on Table 5, the black soil cover had positive and significant effect on auxiliary branch number (6.1). The results of this experiment are in line with the findings of El-Sharony *et al.* (2015) in mango tree. They noted that foliar application of algae extract increased shoot length, shoots number and average leaf area. The increase in shoot growth parameters might be due to the macronutrients (N and K) content in seaweed extracts. Macronutrients have pivotal roles in plant nutrition and are essential for the normal growth and development of the plants (Bokhtiar and Sakurai 2005). Moreover, the positive effects of soil cover (on maintaining soil moisture and reducing weed growth) on plant growth should not be ignored.

Umbel number per plant

The highest umbel number was recorded with 4 mlL^{-1} Stimplex foliar application (Table 4). Umbel number was also influenced by the soil cover and the highest number (4.2) belonged to the black cover (Table 5). The results of this experiment are in agreement with the findings of Zodape *et al.* (2011) in tomato plants. In their study, the foliar application of brown-algae extract had positive effect on plant yield mainly due to the fact that the extract is rich in vitamins, micro and macro elements and growth promoting hormones (auxin, cytokine, GA_3). It seems that the availability of cytokinins may affect the cell division (Koda and Okazawa 1983) and also the mobilization of assimilates towards the growing tissues of plant (Helgeson 1968) in favor of productivity. Imliwatjamir *et al.* (2016) revealed that using mulch improved the nutrient availability and yield in soybean plants.

Table 4. Means of Stimplex foliar application levels for some characteristics of *Coriandrum sativum* L. averaged over soil cover types and locations.

Stimplex foliar application	Above-ground biomass (gm^{-2})	Auxiliary branch number	Plant height (cm)	Umbel number per plant	Total soluble solids (°Brix)	P (%)	K (%)
0	51.90[b]	3.9 [b]	18.9[b]	2.7[b]	1.3[b]	0.21[b]	1.4[b]
2	60.31[a]	5.6[a]	30.6[a]	3.8[a]	2.3[a]	0.29[a]	2.2[a]
4	59.34[a]	5.7[a]	30.6[a]	4.2[a]	2.3[a]	0.28[a]	2.3[a]
6	57.10[a]	5.2[a]	29.1[b]	3.6[ab]	2.4[a]	0.29[a]	2.3[a]

Means with similar letters in each columns are not significantly different based on Duncan's test at $p\leq 0.05$.

Table 5. Means of soil cover types for some characteristics of *Coriandrum sativum* L. averaged over Stimplex foliar application levels and locations.

Soil cover	Above-ground biomass (gm^{-2})	Auxiliary branch number	Plant height (cm)	Umbel number per plant	Chlorophyll a (mg g^{-1} FWt)	Total soluble solids (°Brix)	P (%)	K (%)
Control	54.8[b]	4.70[b]	22.4[b]	3.4[b]	1.22[b]	1.8[b]	0.24[b]	1.90[b]
Black cover	60.3[a]	6.16[a]	30.6[a]	4.2[a]	1.52[a]	2.4[a]	0.31[a]	2.96[a]
White cover	56.4[b]	4.78[b]	28.8[a]	3.2[b]	1.30[b]	1.9[b]	0.25[b]	2.18[a]

Means with similar letters in each columns are not significantly different based on Duncan's test at $p\leq 0.05$.

Above-ground biomass

All Stimplex foliar application treatments increased the above-ground biomass in *C. sativum* (Table 4). This positive effect might be due to the presence of suitable amounts of N and K (as shown in Table 2) as well as growth promoting substances like cytokinin in Stimplex. Cytoknins take part in the nutrients mobilization and have roles in fruits set and development (Helgeson 1968). Foliar application of algae extract increased number of fruits per plant and fruit yield in tomato (Saravanan *et al*. 2003; Nour *et al.* 2010; Zodape *et al.* 2011) and number of leaves, plant height, number of branches and dry weight of fenugreek (*Trigonella foenum-graecum* L.) (Shahira *et al.* 2015). Improving chlorophyll content of the leaves, facilitating carbon movement as well as improving net photosynthesis rate may have contributed to the fruit yield in tomato (Zodape *et al.* 2011).

As Table 3 shows, soli cover had significant effect on biomass and the black polyethylene with 60.3 gm^{-2} biomass was significantly higher than the control (Table 5). The results of the present experiment are in agreement with the findings of El-Yazid and Mady (2012) in strawberry plants. The research conducted by Zhai *et al*. (2006) showed that soil covers increased dry weight of the plant and total yield in cucumbers.

Root dry weight

The soil cover × location and foliar application × location interactions were significant for root dry weight (Table 3). The highest root dry weight (15 gm^{-2}) was recorded in the city of Sarab with black soil cover (Table 7). Also, the highest root dry weight was recorded in Sarab at 6 ml L^{-1} Stimplex foliar application (Table 8). In a study, application of algae extract increased root length in olive (Haggag *et al.* 2014). Effects of algae extract on root dry weight might be attributed to the presence bio-stimulators, which affect the root growth and development (Calvo *et al.* 2014). Furthermore, the stimulated root growth may be due to the availability of nutrients to aerial parts and possibly higher photosynthesis and translocation of assimilates towards roots.

Chlorophylls content

Effect of soil cover was significant on chl a content (Table 3). The highest value for chl a content (1.5 mg g^{-1} FWt) was recorded with black soil cover (Table 5). Vojodi Mehrabani *et al.* (2016) also showed the increase in chl a and total chl content by the application of black soil cover in *C. officinalis*. The positive impact of algae extract on chlorophyll content may be due to the minerals content of the extract.

TSS

TSS concentration was significantly influenced by the Stimplex foliar application, type of soil cover and location (Table 3). TSS concentration increased significantly ($p \leq 5\%$) in all Stimplex treatments as compared to the control (Table 4).

Location (Table 6) and soil cover (Table 5) independently influenced TSS concentration and the highest values were recorded for Sarab (2.2 ^{0}Brix) and black soil cover (2.4 ^{0}Brix). The results were in agreement with those obtained by El-Sharony *et al.* (2015) in mango and Najafabadi *et al.* (2012) in garlic. A possible reason for increasing TSS concentration in our experiment might be due to positive effects of algae extracts on photosynthesis. The increased availability of macro and micro elements accelerates photosynthetic potential and hence improves carbohydrates content. Also, Ni *et al*. (2016) reported that mulching improved plant growth by increasing root activity, soluble sugar and chlorophyll a content and providing suitable moisture conditions and nutrients in the root zone.

N, P and K concentration

Analysis of variance showed the significant Stimplex foliar application × soil cover interaction for the nitrogen concentration of plants (Table 3). The highest value (2.8%) belonged to the black soil cover at 2 ml L^{-1} Stimplex foliar application (Table 9). There were significant differences between locations for N and K contents (Table 3). The highest values for N (2.09%) and K (2.2%) content belonged to the city of Sarab (Table 6). Percentage of P was increased by all foliar applications as compared to the control treatment (Table 4). Furthermore, the highest value of P concentration belonged to the black soil cover (Table 5). Both white and black soil covers increased K content (Table 5). The improved contents of elements observed in this study might

Table 6. Means of locations for some characteristics of *Coriandrum sativum* L. averaged over soil cover types and Stimplex foliar application levels.

Location	Auxiliary branch number	Total soluble solids (°Brix)	N (%)	K (%)
Sarab	5.4[a]	2.2[a]	2.09[a]	2.24[a]
Shabestar	4.8[b]	1.9[b]	1.60[b]	2.02[b]

Means with similar letters in each columns are not significantly different based on Duncan's test at $p\leq 0.05$.

Table 7. Means of soil cover types in each location for some characteristics of *Coriandrum sativum* L. averaged over Stimplex foliar application levels.

Place	Soil cover	Root dry weight (gm^{-2})	IC_{50} ($mg\ ml^{-1}$)
Sarab	Control	12.2[b]	2.05[ab]
Sarab	Black cover	15.0[a]	1.93[ab]
Sarab	White cover	12.1[b]	2.28[a]
Shabestar	Control	11.7[b]	2.27[a]
Shabestar	Black cover	12.6[b]	1.77[b]
Shabestar	White cover	11.9[b]	1.60[b]

Means with similar letters in each columns are not significantly different based on Duncan's test at $p\leq 0.05$.

Table 8. Means of Stimplex foliar application levels in each location for some characteristics of *Coriandrum sativum* L. averaged over soil cover types.

Location	Stimplex foliar application level (mlL^{-1})	Root dry weight (gm^{-2})	Essential oil content (%)
Sarab	0	11.4[c]	0.070[d]
Sarab	2	12.4[bc]	0.110[a]
Sarab	4	13.1[b]	0.100[b]
Sarab	6	14.4[a]	0.100[bc]
Shabestar	0	11.3[c]	0.050[e]
Shabestar	2	13.1[bc]	0.080d
Shabestar	4	12.5[bc]	0.080[d]
Shabestar	6	11.3[c]	0.089[cd]

Means with similar letters in each columns are not significantly different based on Duncan's test at $p\leq 0.05$.

be due to the possible effects of nutritional elements, such as N and K, contained in Stimplex. Nour *et al.* (2010) described that alge extract foliar application upraised N, P and K content of plants and subsequently, improved the plant yield. Similar results were reported by El-Sharony *et al.* (2015) in mango, Abd El Moniem and Abd-Allah (2008) in grapevine and Shahira *et al.* (2015) in fenugreek. El-Yazid and Mady (2012) reported that foliar applications with 1000 ppm potassium and red bed cover mulch resulted in the highest amounts of photosynthetic pigments, nitrogen, phosphorus and potassium concentrations and total sugars in the leaves of strawberry shoots. The same results were reported by Imliwatjamir *et al.* (2016) upon using straw mulch, and anti-transpirant agent improved the N, P and K concentration of soybean plants.

Antioxidant potential

Effects of location, soil cover and location × soil interaction on IC_{50} were significant (Table 3). The lowest IC_{50} (1.6 and 1.7 mg ml^{-1}) belonged to the white and black soil covers in Shabestar, respectively, that had significantly better performance than the control (Table 7). Vojodi Mehrabani *et al.* (2018) reported that seaweed application increased antioxidant capacity of *Lepidium sativum.* In a research conducted by Fan *et al.* (2012), soil covers had positive effects on enhancing antioxidant capacity in the strawberry plants. Based on Jasim *et al.* (2014), mulch and high K treatment led to increased broccoli tolerance to salt stress by improving antioxidant pools.

Total phenolics and flavonoids contents

Total phenolics and flavonoids contents were influenced by Stimplex foliar application × soil cover interaction (Table 3). The highest values for the total phenolics content were obtained for the black soil cover at all Stimplex foliar applications, which were significantly different than other treatment combinations including the control plants (Table 9). Also, according to Table 9, the highest amount of flavonoids content was recorded for the black soil cover at 2 ml L^{-1} Stimplex foliar application (19.8 mg g^{-1}DWt). Vojodi Mehrabani *et al.* (2018) also reported the positive effect of algal extract on total phenolics content in *Lepidium sativum.* Phenolic compounds are important components responsible for the antioxidant capacity in plants (Fan *et al.* 2012). In a study, foliar spray with algae + garlic extract increased ascorbic acid content in mango as compared to the control treatment (El-Sharony *et al.* 2015). Najafabadi *et al.* (2012) observed the usefulness of soil cover in increasing ascorbic acid and flavonoids contents in garlic. Taie *et al.* (2010) reported that the application of organic fertilizer instead of chemical fertilizers on basil plants increased total phenolics and flavonoids content in plants. Similar results were reported by Vojodi Mehrabani *et al.* (2016) in *C. officinalis.*

Essential oil content

The result showed that foliar application of Stimplex × location and foliar application of Stimplex × soil cover interactions were significant for the essential oil content (Table 3). The highest essential oil content (0.11%) was recorded in Sarab with 2 ml L^{-1} Stimplex foliar application (Table 8). Also, Table 9 shows that the application of 2 ml L^{-1} Stimplex + black soil cover resulted in the highest essential oil content (0.12%). The results are similar with the findings of Vojodi Mehrabani *et al.* (2016) in *C. officinalis* in response to the use of soil cover. Seemingly, the reason for increasing essential oil content in our study was due to increasing soil temperature caused by black soil cover that encourage plant growth and essential oil accumulation. Shahira *et al.* (2015) reported that algal extract improved fenugreek oil content. It seems that the algal extract fortifies essential oil content by improving the availability of nutrients and hence by accelerating photosynthetic potential and partitioning of substrates in favor of essential oil biosynthesis and accumulation.

Table 9. Means of Stimplex foliar application levels in each soil cover type for some characteristics of *Coriandrum sativum* L. averaged over locations.

Soil cover	Stimplex foliar application (ml L^{-1})	Essential oil content (%)	Total phenolics compounds (mg GAg^{-1} DWt)	Flavonoids content (mg g^{-1}DWt)	N (%)
Control	Control	0.06^{d}	40.5^{e}	6.8^{ef}	1.1^{f}
Control	2	0.08^{bcd}	59.3^{bc}	9.9^{def}	1.9^{e}
Control	4	0.08^{bcd}	59.8^{bc}	11.9^{bcd}	1.9^{e}
Control	6	0.08^{bcd}	63.0^{bc}	12.6^{bcd}	2.0^{de}
Black cover	Control	0.05^{cd}	53.6^{cd}	7.8^{def}	1.5^{f}
Black cover	2	0.12^{a}	94.0^{a}	19.8^{a}	2.8^{a}
Black cover	4	0.10^{b}	88.6^{a}	14.9^{bc}	2.3^{bcd}
Black cover	6	0.12^{b}	88.3^{a}	15.7^{b}	2.3^{bcd}
White cover	Control	0.06^{d}	45.8^{de}	6.0^{f}	1.4^{f}
White cover	2	0.09^{bc}	70.3^{b}	10.1^{cdef}	2.2^{bcde}
White cover	4	0.09^{bc}	68.3^{b}	1.0^{bcde}	2.3^{bcd}
White cover	6	0.09^{bc}	64.1^{bc}	9.1^{def}	2.1^{cde}

Means with similar letters in each columns are not significantly different based on Duncan's test at $p \leq 0.05$.

Conclusions

Location, algal extract and soil cover affected *C. sativum* yield and quality in this study. The positive effects of Stimplex foliar application on vegetative growth and some physiological traits of *C. sativum* were seemingly due to the rich content of minerals, cytoknins and other useful nutrients in the Stimplex. Also, polyethylene soil cover improves soil temperature, moisture content and even reduce weed incidence in the soil, especially in temperate regions. The results obtained from this experiment showed that using black polyethylene soil cover had positive effects on the plant growth and quality. The growth location also had prominent influence on the plant growth parameters. The *C. sativum* plants had more favorable growth potential in the city of Sarab. The possible reason for the improved growth parameters under cold weather of Sarab may be due to the reduced respiration rate and increased partitioning and availability of assimilates in the plant.

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تاثیر خاکپوش و محلول‌پاشی برگی با استیمپلکس (*Ascophyllum nodosum*) بر ویژگی‌های آنتی‌اکسیدانی و برخی ویژگی‌های فیزیولوژیک گشنیز

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چکیده

دو آزمایش جداگانه مزرعه‌ای به صورت فاکتوریل و بر مبنای طرح بلوک‌های کامل تصادفی به منظور مطالعه تاثیر خاکپوش (شاهد، سیاه و سفید)، محلول‌پاشی برگی با غلظت‌های مختلف کود استیمپلکس (صفر، ۲، ۴ و ۶ میلی‌لیتر در لیتر) و مکان (شهرستان‌های سراب و شبستر) بر رشد و برخی صفات فیزیولوژیک گشنیز انجام شد. بالاترین محتوای اسانس، فلاونوئید، درصد نیتروژن، در تیمار خاکپوش سیاه + ۲ میلی‌لیتر در لیتر کود استیمپلکس و بالاترین محتوای فنل در تیمار خاکپوش سیاه در ۲، ۴ و ۶ میلی‌لیتر در لیتر کود استیمپلکس مشاهده شد. بیشترین وزن خشک ریشه و محتوای اسانس به ترتیب در سطوح ۶ و ۲ میلی-لیتر در لیتر کود استیمپلکس در شهرستان سراب مشاهده شد. بهترین میزان IC_{50} در شهرستان شبستر در تیمارهای خاکپوش سیاه و سفید (به ترتیب ۱/۶ و ۱/۷ میلی‌گرم در میلی‌لیتر) مشاهده شد. تیمار محلول‌پاشی اثر معنی‌داری بر بیوماس هوایی گشنیز، ارتفاع گیاه، تعداد شاخه‌های جانبی، تعداد چتر در بوته، محتوای مواد جامد محلول کل و محتوای فسفر و پتاسیم داشت. تعداد شاخه‌جانبی، محتوای مواد جامد محلول و محتوای نیتروژن و پتاسیم بیشتری در شهرستان سراب نسبت به شبستر ثبت شد. خاکپوش سیاه موجب افزایش درصد پتاسیم و فسفر، محتوای مواد جامد محلول کل، کلروفیل a، تعداد چتر در بوته، بیوماس هوایی، تعداد شاخه‌های جانبی و ارتفاع گیاه شد. در کل نتایج حاصل از آزمایش انجام شده نشان داد که استفاده از خاکپوش سیاه و محلول‌پاشی با عصاره جلبک (۲ میلی‌لیتر در لیتر) موجب افزایش رشد و بهبود صفات فیزیولوژیک گشنیز گردید.

واژه‌های کلیدی: پیش تیمار؛ خصوصیات رشدی؛ زوال بذر؛ گیاهچه صفات بیوشیمیایی؛ هیبریدهای

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