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Full Length Research Paper

Effect of P_2O_5 on coriander induced by AMF under water deficit stress

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This experiment was carried out using a split factorial based randomized complete block design with 4 replications. The factors studied included two levels of drought stress, application and non-application of mycorrhiza (*Glomus hoi*) and 0, 35 and 70 kg ha^{-1} phosphorus applications. The results showed that drought stress had significant effect on essential oil yield, biological yield, shoot P content, root yield, seed yield and harvest index and the highest upon plant characteristics were achieved under without drought stress condition. Also, mycorrhiza and phosphorus application had significant effects on essential oil yield, biological yield, shoot P content, root yield and seed yield. Highest of this characteristics were achieved under application of mycorrhiza and 70 kg ha^{-1} phosphorus.The findings indicated that AMF inoculation of coriander contributes to improved water and phosphorous uptake for the production of below-ground organs and helps maintain accumulation of dry matter.

Key words: Arbuscular mycorrhizal fungi, phosphorus, drought stress, essential oil, *Coriandrum sativum*.

INTRODUCTION

Mycorrhizal fungi live in a ‘symbiotic’ relationship with plants. They grow in close association with the roots and play an important role in the concentration and transfer of soil nutrients to the plant. In exchange, the plant supplies the fungus with sugars. In some cases of poor establishment of young plants, especially from seed, this can be associated with failure to establish a mycorrhizal relationship with suitable fungi (Auge, 2001). The results of experiment on coriander showed that fruits of GM-inoculated plants contained 28% more essential oil than those of control plants and GF inoculation resulted in about 43% increase in essential oil concentration in fruits as compared with control fruits. The increased essential oil yield in coriander on VAM inoculation may be due to improved P uptake (Kapoor et al., 2001) . The effect of root colonization by *Glomus mosseae* on the qualitative and quantitative pattern of essential oils (EO) was determined in three oregano genotypes (*Origanum* sp.) showed that EO concentration significantly increased. As EO levels in P-treated plants were not enhanced, we conclude that the EO increase observed in mycorrhizal oregano plants is not due to an improved P status in mycorrhizal plants, but depends directly on the AMF-oregano plant association (Khaosaad et al, 2006). A field experiment was conducted to study and compare the effectiveness of two arbuscular mycorrhizal fungi (AMF), *Glomus macrocarpum* (GM) and *Glomus fasciculatum* (GF) on three accessions of *Artemisia annua*. The AM inoculation significantly increased the production of herbage, dry weight of shoot, nutrient status (P, Zn and Fe) of shoot, concentration of essential oil and artemisinin in leaves as compared to non-inoculated plants (Chaudhary et al., 2007) . Results of the effects of different species of arbuscular mycorrhizal fungi on the vegetative growth, production and composition of essential oil of *Mentha arvensis* L., grown in different phosphorus levels When phosphorus was not used, the essential oil content and menthol levels in the oil were smaller in plants not inoculated, and the inoculated treatments provided increments of up to 89% in the essential oil and menthol contents in relation to treatment not inoculated. No increment in essential oil and menthol contents occurred when the doses of P were increased. The highest essential oil and menthol production, 0.69

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Table 1. The results of soil analysis.

Soil texture	Sand (%)	Silt (%)	Clay (%)	K mg/kg	P mg/kg	N mg/kg	Na Ds/m	EC 1: 2.5	pH	Depth of sampling
Sa	49	30	21	147.2	6.2	34.7	0.04	0.19	8.1	0 - 15 cm
Sa. c. L	56	25	19	124.3	3.7	28.2	0.03	0.16	7.9	15 - 30 cm

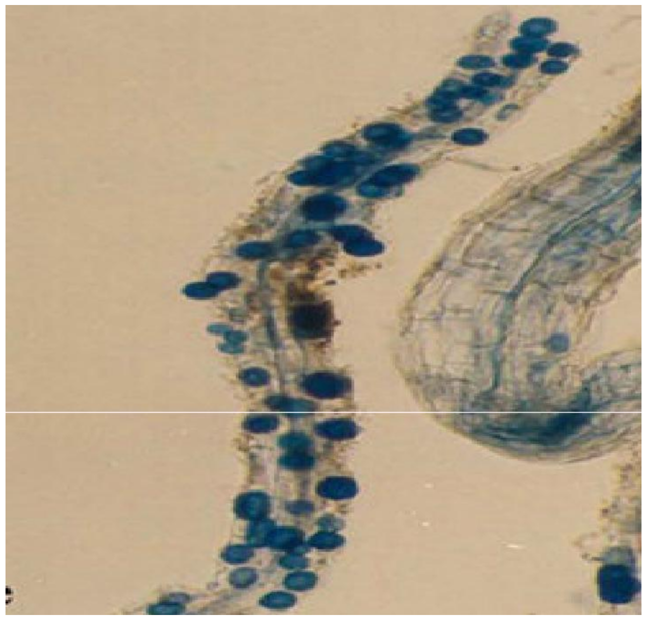

Figure 1. Symbiosis of mycorrhiza.

and 0.48 g for pot, respectively, were found in plants inoculated with *A. scrobiculata* at the P levels and 126 and 123 mg for kg of soil, respectively (Freitas et al., 2004).

MATERIAL AND METHODS

This study was carried out at the Iran Research Institute of Forest and Rangelands in 2006. The field experiment was carried out in a split factorial based randomized complete block design with 4 replications. The factors which studied were two level drought stress that irrigation after 30 mm water evaporation from evaporation pan (without stress conditions) and irrigation after 60 mm water evaporation (drought stress conditions), application and non-application of mycorrhiza (*Glomus hoi*) and 0, 35 and 70 kg ha^{-1} phosphorus fertilizer (super phosphate triple). The irrigation system was a piping system and determined water used in each irrigation period and amount of water for each irrigation treatments was 17.28 m^{-3} in each period and also in the vegetation period of this experiment didn't natural precipitation. Selected varied P fertilization in the experimental program until symbiosis rate studied in different levels of phosphorus conditions. The soil consisted of 21% clay, 30% silt and 49% sand (Table 1).

The soil bulk density was 1.4 g cm^{-3} and further the field was prepared in a 15 m^2 area (5 × 3 m) totally 48 plots. *Glomus hoi* was provided from the Department of Biosafety and Microorganisms, Agricultural Biotechnology Research Institute of Iran (ABRII) which was consisting of root fragments and adhering spores mixed with soil (90 - 110 propagules per 10 g soil). Shahabdolazimi variety is a native variety that used in experiment. It planted in first of May month and germinated next of 21 days. Nitrogen fertilizer added in two periods that 75 kg ha^{-1} urea in first of steming stage and 75 kg ha^{-1} urea in first of flowering stage also 150 kg ha^{-1} potash fertilizer and phosphorus treatments added in planting date. At the end of growth stage we collected plants for determined symbiosis of mycorrhiza and coriander root. The degree of internal colonization produced by each entophyte in the roots of plants was rated by observation under a microscope. Root segments were clarified and stained with trypan blue (Philips and Hayman, 1970). The extent of root colonization was estimated by comparison of root length between inoculated and non-inoculated plants as well as root length having hyphae. The results illustrated that coriander inoculated with *Glomus hoi* displayed 60 - 71% root colonization with *Glomus hoi* (Figures 1 and 2).

Also, 2.0 g dry matter from each plot was digested in a 40:4:1 (v/v/v) mixture of nitric, perchloric and sulphuric acid for the analysis of phosphorus and was determined shoot P content in Soil and Water Research Institute of Iran (SWRII). The phosphorus in the digested samples was estimated according to Allen and Boosalis (1983). End of august month was harvest stage and we collected 100 plants from each plot by chance for determined plant characteristics and essential oil exited from 100 g seeds samples with 4 replications by Clevenger (Noudjou et al., 2007). Data were subjected to analysis of variance (ANOVA) using Statistical

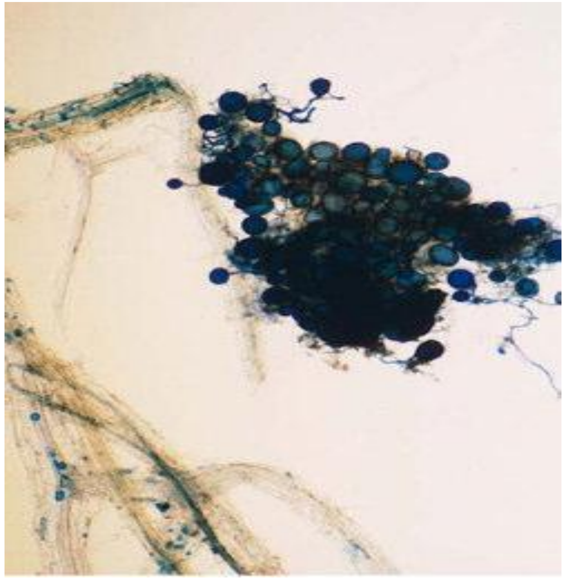

Figure 2. Coriander root.

Table 2. Analysis of variance.

Mean squares							
Root yield	**Shoot P content**	**Harvest index**	**Biological yield**	**Seed yield**	**Essential oil yield**	**df**	**Value sources**
162755.694	0.013*	0.0001	2784427.439**	193579.886**	5.023**	3	Replication
360317.291*	0.007*	0.001	1525025.622**	203525.065**	5.481**	1	Mycorrhiza
17703.73	0.001	0.0001	4426.025	3882.029	0.43	3	Error a
291690.374**	0.004*	0.001	1037099.492**	122925.354**	2.524**	2	Phosphorus
102190.046	0.001	0.0001	89182.982	9158.4	1.704**	2	Mycorrhiza × Phosphorus
14969087.337**	0.195**	0.0001*	200069341.98**	8811994.332**	109.336**	1	Drought Stress
1736.263	0.001	0.0001*	459808.1*	76493.086**	0.273	1	Mycorrhiza × Drought stress
142939.147*	0.002	0.0001*	334679.076**	56418.305**	1.319**	2	Phosphorus × Drought stress
3072.814	0.001	0.0001	2609.43	1696.312	0.57	2	Mycorrhiza × Phosphorus × Drought stress
39184.251	0.001	0.0001	61695.11	7164.741	0.181	30	Error bc
9.2	8.14	3.09	4. 52	7.16	9.27		CV (%)

*And **: Significant at 5% and 1% levels respectively.

Analysis System and followed by Duncan's multiple range tests. Terms were considered significant at $P < 0.05$ (SAS institute Cary, USA, 1988).

RESULTS

The results showed that drought stress significantly effects essential oil yield, biological yield, shoot P content, root yield and seed yield (= 1%) and harvest index (= 5%) (Table 2) and the highest biological yield (7538.8 kg ha^{-1}), shoot P content (12.7 kg ha^{-1}), essential oil yield (6.1 kg ha^{-1}), root yield (2659.0 kg h^{-1}), seed yield (1610.5 kg ha^{-1}) and harvest index (21.4%) appeared under without drought stress conditions (Table 3). Mycorrhiza

Table 3. Means comparison.

Harvest index (%)	Essential oil yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Root yield (kg ha^{-1})	Shoot P content (kg ha^{-1})	Biological yield (kg ha^{-1})		Treatments
20.1 a	5.9 a	1247.5 a	2196.0 a	7.8 a	5705.5 a	Application	Mycorrhiza
20.3 a	5.1 b	1107.3 b	2008.1 b	6.6 b	5319.0 b	Non application	
20.6 a	4.1 c	988.2 c	1915.2 c	4.1 c	5035.8 c	Non application	Phosphorus
21.6 a	4.6 b	1188.7 b	2153.2 b	7.9 b	5495.5 b	35 kg ha^{-1}	
21.9 a	5.9 a	1249.0 a	2203.0 a	11.1 a	5702.3 a	70 kg ha^{-1}	
21.4 a	6.1 a	1610.5 a	2659.0 a	12.7 a	7538.8 a	Non stress	Drought stress
17.37 b	3.5 b	600.3 b	1510.4 b	3.1 b	3455.6 b	Drought stress	

Means within the same column and rows and factors, followed by the same letter are not significantly difference ($P < 0.05$).

significant effect on biological yield, essential oil yield and seed yield (= 1%) and shoot P content and root yield (= 5%) (Table 2) and the highest biological yield(5705.5 kg ha^{-1}), shoot P content (7.8 kg ha^{-1}), seed yield (1247.5 kg ha^{-1}), root yield (2196.0 kg ha^{-1}) and essential oil yield (5.9 kg ha^{-1}) appeared under application of mycorrhiza (Table 3). Also, the results showed that phosphorus significant effect on essential oil yield, biological yield, root yield and seed yield (= 1%) and shoot P content (= 5%) (Table 2) and a means comparison showed that the highest biological yield (5702.3 kg ha^{-1}), shoot P content (11.1 kg ha^{-1}), root yield (2203.0 kg ha^{-1}), seed yield (1249.0 kg ha^{-1}) and essential oil yield (5.9 kg ha^{-1}) appeared under application of 70 kg ha^{-1} phosphorus (Table 3). Means comparison showed that the highest biological yield (5703.0 kg ha^{-1}), shoot P content (11.5 kg ha^{-1}) and seed yield (2301.0 kg ha^{-1}) appeared under application of mycorrhiza and 70 kg ha^{-1} phosphorus and the highest root yield (2279.0 kg ha^{-1}) and essential oil yield (5.1 kg ha^{-1}) appeared under application of mycorrhiza and 35 kg ha^{-1} phosphorus (Table 4). The highest biological yield (7815.0 kg ha^{-1}), shoot P content (13.3 kg ha^{-1}), seed yield (1420.0 kg ha^{-1}), root yield (2190.0 kg ha^{-1}), essential oil yield (6.5 kg ha^{-1}) and harvest index (20.5%) appeared under application of mycorrhiza and without drought stress conditions (Table 4). Also, the highest biological yield (7936.0 kg ha^{-1}), shoot P content (12.7 kg ha^{-1}), seed yield (1558.0 kg ha^{-1}), root yield (2908.0 kg ha^{-1}), essential oil yield (6.8 kg ha^{-1}) and harvest index (22.1%) appeared under application of 70 kg ha^{-1} phosphorus and without drought stress conditions (Table 4). The results of means comparison showed that highest biological yield (8161.0 kg ha^{-1}), shoot P content (12.4 kg ha^{-1}), seed yield (1819.0 kg ha^{-1}), root yield (2927.0 kg ha^{-1}), essential oil yield (6.7 kg ha^{-1}) and harvest index (22.2%) appeared under application of mycorrhiza, 70 kg ha^{-1} phosphorus and without drought stress conditions (Table 4).

DISCUSSION

Absorb of phosphorus is by plants in forms $H_2SO_4^-$ and HSO_4^{-2} that for absorb of this anion, pH of soil must be acidic. Hyphaes of mycorrhiza splash solvent acid of phosphorus (For example: Malic acid) that cause increasing absorb of phosphorus by plan in non-acid soils. Essential oil yield increased by mycorrhiza because application of mycorrhiza increased absorb of phosphorus by plan and also, phosphorus increased biological yield. Therefore each factor that increase of biological yield cause increasing of essential oil yield, finally mycorrhiza and phosphorus increased essential oil yield in Coriander. Also, decreased essential oil yield under drought stress conditions because in these conditions, plant deleted surplus leafs and decreased leafs area and also closed or semi closed it stomatals because least of water wasted by evapotranspiration. Therefore Coriander optimum used from water for product dry matter and caused that decreased essential oil yield in these conditions. Plants colonized by mycorrhizal fungi have been shown to deplete soil water more thoroughly than non-mycorrhizal plants (Auge, 2001). One reason for this is the fact that the shoots of plants with AMF usually have a larger biomass (more evaporative leaf surface area) than non-AMF plants (Fitter, 1985; Nelsen, 1987). Also the root systems of plants with AMF are often more finely divided and thus have more absorptive surface area (Allen et al., 1981; Busse and Ellis, 1985; Ellis et al., 1985; Huang et al., 1985; Sharma and Srivastava, 1991; Osonubi et al., 1992; Osonubi et al, 1994; Okon et al., 1996).

Furthermore, the roots of plants with AMF dry the soil more quickly than non-AMF plants of similar size

Table 4. Means comparison of interaction.

Harvest Index (%)	Essential oil yield (kg ha^{-1})	Root yield (kg ha^{-1})	Shoot P content (kg ha^{-1})	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Survey instance qualifications			
21.7 a	3.6 d	1868.3 c	4.1 e	1768.0 c	5177.1 e	Non application of phosphorus			
21.7 a	4.2 c	2058.2 d	7. 9 c	2058.1 d	5407.1 c	35 (kg ha^{-1}) phosphorus		Non application	
21.9 a	5 a	2201.0 a	11.1 a	2201.1 a	5511.1 b	70 (kg ha^{-1}) phosphorus			Mycorrhiza
22.1 a	4.8 b	2062.1 b	5. 2 d	2063.0 b	5371.2 c	Non application of phosphorus			
22.2 a	5.1 a	2279.1 a	9. 3 b	2279.1 a	5601.1 b	35 (kg ha^{-1}) phosphorus		Application	
22.3 a	5 a	2239.0 a	11.5 a	2301.0 a	5703.0 a	70 (kg ha^{-1}) phosphorus			
19.1 b	5.7 b	2106.2 b	12.7 b	1301.2 b	7263.1 b	Non stress		Non application	
17.1 d	2.8 d	1416.3 d	3.1 d	600.1 d	3536.1 c	Stress			Mycorrhiza
20.5 a	6.5 a	2190.0 a	13.3 a	1420.0 a	7815.0 a	Non stress		Application	
17.8 c	3.4 c	1603.3 c	4 c	679.2 c	3536.1 c	Stress			
19.3 c	5.5 b	2319.1 c	9. 6 c	1201.4 c	7139.1 c	Non application of phosphorus			
21.1 b	5.8 b	2760.1 b	11. 3 b	1423.2 b	7545.1 b	35 (kg ha^{-1}) phosphorus		Non stress	
22.1 a	6.8 a	2908.0 a	12.7 a	1558.0 a	7936.0 a	70 (kg ha^{-1}) phosphorus			Drought stress
17.1 f	2.8 d	1412.2 e	2. 5 e	609.2 f	3333.3 f	Non application of phosphorus			
18.1 e	3.3 c	1577.3 d	3. 5 d	638.1 e	3484.4 e	35 (kg ha^{-1}) phosphorus		Stress	
18.4 d	3.1 cd	1542.2 d	3.7 d	695.3 d	3553.3 d	70 (kg ha^{-1}) phosphorus			
20.1 e	4.7 c	2216.4 c	7.4 c	1347.2 e	6904.1 e	Non application of phosphorus			
20.7 e	5.6 b	2661.1 b	9. 2 b	1388.1 d	7173.3 de	35 (kg ha^{-1}) phosphorus	Non stress		
21.8 d	6.9 a	2890.0 a	10. 3 b	1682.1 bc	7711.1 bc	70 (kg ha^{-1}) phosphorus		Non application	
18.1 g	2.5 e	1319.1 f	2. 2 e	671.1 f	3265.1 i	Non application of phosphorus			
19.1 f	2.9 e	1454.1 ef	3. 5 d	731.5 f	3235.2 i	35 (kg ha^{-1}) phosphorus	Stress		
19.2 f	3.1 e	1474.1 ef	3. 6 d	766.5 f	3536.1 h	70 (kg ha^{-1}) phosphorus			Mycorrhiza

Table 4. Contd.

21.3 c	6.5 a	2621.2 b	9.1 c	1569.1 cd	7373.3 c	Non application of phosphorus		
22.1 b	6.4 a	2558.0 a	10.2 b	1758.2 ab	7911.1 b	35 (kg ha^{-1}) phosphorus	Non stress	
22.2 a	6.7 a	2927.0 a	12.4 a	1819.0 a	8161.0 a	70 (kg ha^{-1}) phosphorus		
								Application
17.1 hi	3.1 e	1505.1 e	3.1 e	752.1 f	3570.1 h	Non application of phosphorus		
17.2 h	3.8 d	1699.2 d	4. 3 d	800.1 f	3637.2 g	35 (kg ha^{-1}) phosphorus	Stress	
17.5 h	3.2 e	1608.3 de	4.4 d	783.6 f	4301.4 f	70 (kg ha^{-1}) phosphorus		

Means within the same column and rows and factors, followed by the same letter are not significantly difference ($P < 0.05$) using Duncan's multiple range test.

(e.g., Bryla and Duniway, 1997). In our experiment, mycorrhizal coriander significantly essential oil yield throughout the improvement plant water relations under drought conditions corresponding of mycorrhiza's contribution in P uptake to AMF-plants and act to synthesis of certain phytohormones as like as ABA and cytokinin. In the present study, mycorrhizal (*Glomus hoi*) treatment of coriander significantly improved essential oil yield through improvement of plant water relations under drought conditions. These improvements were likely achieved via the mycorrhizal contribution to phosphorous uptake and the ability of AMF to stimulate plant synthesis of certain phytohormones such as ABA and cytokinins. Consequently, plants with AMF had higher phosphorous content in shoots than non-AMF plants, in agreement with the observation of Labour et al. (2003) and Dhanda et al. (2004) our data also revealed that roots of AMF-inoculated coriander were longer with increasing fungal hyphae growth, similar to the findings of Ruiz-Lozano et al (1995). Our findings indicate that mycorrhiza application increased phosphorus absorb and increased shoot P content and essential oil yield of coriander.

Conclusion

The investigation showed that AM is able to enhance the growth of coriander under water stress through enhancing P uptake. This can have very important environmental implications through decreasing the amount of P fertilizer under control and water stress conditions and also through enhancing the coriander resistance when subjected to the water stress.

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