

Caspian Coastal Forests: Arbuscular Mycorrhizal Fungi and Understory Vegetation

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Abstract

Moist and temperate Caspian forests are associated with a diversity of soil types and topography. Although, natural history and ecological attributes of the Caspian vegetation is well-documented, little is known about mycorrhizae of the Caspian (Hyrcanian) flora. Samples of herbaceous plant species were collected from 4 pre-determined altitudes (-13 upto about 1500m above sea level, approximately 500 m apart from three selected areas (Javaherdeh,J; Dalkhani,D; and Tonekabon,T) in October 2014. In addition, soil samples were collected from top 30 cm and analyzed for their physicochemical properties, mycorrhizal occurrence in roots and fungal spore density and diversity. Forty nine plant species from 30 families were sampled, identified and preserved. *Brachypodium sylvaticum* (Huds.) P. Beauv. and *Polygonum mite* Schrank. had the most frequent distribution in 4 and 6 of 11 stations, respectively. Results of this research revealed that plant species distribution in different forests varied in corresponding altitudes. However, within each forest, although plant species composition varied with increasing altitude and usually one species dominated in each forest, there were no clearcut ranges between habitats in altitudinal gradients studied here. AM fungal community composition, although unique to each rhizosphere, showed great variation between stations and amongst forests as was for the plant species. Results showed Shanon-Weaver diversity index for fungi generally followed the same pattern for plants. Pielou's evenness indices of fungal species did not vary significantly, but differed within stations in each forest. There was no strong correlation between fungal density and soil elements as well as pH and EC except with contents of Na and clay at lower altitudes which correlated negatively with. We established the importance of mycorrhizal fungal community in development of understory herbaceous vegetation in Caspian forests, emphasizing the importance of elevation from sea level, sodium cation exchange capacity and soil texture in plant community development.

Keywords: *Caspian flora, Hyrcanian flora, AM fungi, Altitude*

1. Introduction

Moist and temperate Hyrcanian forests south of the Caspian Sea are associated with a diversity of soil types and topographically unique geological

strata (Axen, et al., 2001; Davidson et al., 2004) providing ample opportunities for plant community development. The Caspian (Hyrcanian) ecosystems provide many functions and valuable services while providing the main habitats for many plant species of Arcto-Tertiary origin (Akhani, 1998) and unique

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endemic plants, such as *Buxus hyrcana* (Jalili and Jamzad, 1999; Akhani et al., 2010) and as such, necessitating their preservation. However, despite their great conservation importance, the Caspian ecosystems are under severe stress primarily because of urban development and overexploitation of forest and range resources. Although, many authors have contributed to documenting natural history and ecological attributes of the Caspian forests (Djazirei, 1965; Assadollahi, 1980; Rastin, 1983; Akhani, 1998; Jafari et al., 2004, 2010; Naqinezhad et al., 2008; 2012; 2013; 2015; Akhani et al., 2010; Zarif Ketabi et al., 2010; Esmailzadeh et al., 2011; Sefidi et al., 2011), little is known about the symbiotic associations, particularly mycorrhizae, of the 3234 species in the Hyrcanian flora, of which 22 percent are endemic to Iran (Akhani et al., 2010).

Few researchers have contributed to mycorrhizal distribution studies of the coastal Caspian forests (for example Vafadar and Zare-maivan, 2006; Baghvardani and Zare-maivan, 1999), but knowledge of the flora still lacks comprehensive ecological categorization and synthesis both for above ground plant species and their underground symbiotic fungal partners. Although, functional traits (Díaz et al., 2004) have been successfully used to describe ecosystem processes within the Iranian vegetation and studies investigating plant species distribution in relation to environmental factors are frequent, yet the knowledge on understory vegetation of Caspian forests and mycorrhizal associations is not ideal for autecological and phytosociological mapping and even functional categorization based on climate or soil characteristics, for example, identifying a definite trait for assessing plant distribution with respect to soil pH (Cornelissen et al., 2003; Hodgson et al., 2011). Since, each plant population establishes its own niche and symbiotic partnership and functions within the ecosystem, identifying the diversity of mycorrhizal populations of the understory vegetation could provide knowledge on

the distribution of different herbaceous plants in forest communities. The floristic composition of understory vegetation of forests reflects edaphic factors, and as a consequence, could determine composition of symbiotic partners associated with plants. Whether population studies of symbiotic fungi would prove reliable enough to use it in identifying indicator plant species, evaluating site conditions, predicting forest productivity and classifying habitats remains to be answered; however, collaborative data is needed to develop ecological profiling schemes or mathematical models (for example TOPSIS, Memariani and Zare-maivan, 2002) in order to understand the relationships between species and their immediate environment.

Edaphic factors and soil type influence strongly plant distribution and growth and also vary greatly within Caspian forests (Rastin, 1983; Sarmadian and Jafari, 2001; Zarrinkafsh, 2002). In addition, distribution of plant species depends on topographic factors (for example elevation, aspect and slope), amount of rainfall and to biotic factors such as interactions with arbuscular - vesicular mycorrhizal (AM) fungi (Naqinezhad, et al., 2012; Hemavani and Thippeswamy, 2013). Majority (80-90%) of plant species are able to have symbiotic associations with AM fungi which are ubiquitous Zygomycete fungi in the soil (Gerdemann and Nicolson, 1963; Cardon and Whitbeck, 2007). Fungal partner facilitates plant growth mostly by nutrient uptake and resistance to many biotic and abiotic stresses such as pathogens, heavy metals and drought (Jeffries 1987; Nelson, 1987; Weissenhorn et al., 1995; Loth and Hofner 1995; Zare-maivan, 2013). Hence, this association has an important effect on plant survival, diversity, reproduction and species composition which will influence both mycorrhizae and plant dynamics during forest succession (Johnson et al., 1991; Hemavani and Thippeswamy, 2013). Environmental conditions, temperature, soil properties and plant species influence the density and community composition of

AM fungal species (D'Souza and Rodriguez, 2012; Anderson et al., 1984; Johnson et al., 1991; Staddon et al., (2002). In this regard, the purpose of this study is to investigate the correlation between plant and mycorrhizal species with altitude and physiochemical properties of the soil in 3 coastal Caspian forest ecosystems (North of Iran) at 4 elevations in order to better understanding the relationships between species and their immediate environment.

2. Materials and Methods

Soil samples were collected from four pre-determined elevations (about 500 apart) from three selected coastal Caspian forests of Iran (Javaherdeh, J; Dalkhani, D and Tonekabon, T), approximately 10 km apart during October 2014 (Table 1). Soil samples were collected from top 30 cm using steel borer (10 cm diam.) and herbaceous whole plant specimens within four 1*1 m quadrates and taken to the lab for further analysis.

2.1. Soil Elemental Analysis

In order to analyze the mineral content in each soil sample, X-ray fluorescence (XRF) technique was used. The soil samples were labeled and sent to accredited Tarbiat Modares XRF laboratory, at the Geology Engineering Department.

2.2. Plant Species and AM Spore Analysis

Plant species were sampled and counted in randomly distributed triplicate blocks (2 x 2 m) within each of three (10 x 10 m) plots, approximately 20 m apart positioned on the corners of a triangle. Collected plant samples were identified using Flora Iranica and reliable published sources and verified at the herbaria of the Tarbiat Modares University and the Forests and Rangelands Institute, Iran. Ecological data including abundance and frequency and percent coverage were recorded for each plant species at all stations.

Spores in soil were isolated by sieving method and sucrose centrifugation (Gerdemann and Nicolson, 1963), counted by observing under Olympus BH2 dissecting microscope (40×) and reported for each station as per gram dry soil. The spores were identified according to their morphological characteristics such as size, color, spore wall, type of hyphal attachment using polyvinyl alcohol-lactoglycerol and Melzers reagent by observing under Olympus B2 compound microscope (400× to 1000×) (Schenck and Perez, 1990).

2.3. Statistical Analysis

Data were analyzed by one-way ANOVA and Duncan test using SPSS.21 to compare the means to determine significant differences between different series of data ($P \leq 0.05$).

Table 1: Geographical coordinates and altitude from sea level of study areas*

Station	Altitude (m)	N	E	pH	EC $\mu\text{s/cm}$	Soil Type
J ₁	-6	36°54.188	50°39.699	7.6	59	Sandy loam
J ₂	478	36°53.572	50°34.623	7.2	37	Sandy loam
J ₃	968	36°52.361	50°32.654	7.0	29	Sandy loam
J ₄	1419	36°52.035	50°30.392	7.7	47	Clay loam
D ₁	-13	36°52.904	50°44.673	7.7	70	Sand
D ₂	471	36°49.016	50°41.100	7.6	63	Sandy loam
D ₃	921	36°49.133	50°33.706	7.2	24	Loam
D ₄	1408	36°37.687	50°37.050	6.7	64	Sandy loam
T ₁	-12	36°47.828	50°53.965	7.7	62	Loam
T ₂	529	36°39.565	50°43.347	7.5	52	Clay loam
T ₃ **	-	-	-	-	-	-
T ₄	1385	36°33.889	50°44.253	7.7	65	Clay loam

*Subscripts 1= Coastal lowland, 2= Lower Montane, 3=Mid-Montane, 4= Montane

**As the forest was severely disturbed by human activity, it was not sampled.

3. Results

Understory plant communities in Caspian forests were diverse and variable. In this research, herbaceous and mostly rosaceous and similar shrub species frequented the understory of dominant tree species (Table 2). Forty Two plant species from 30 families were sampled, identified and preserved as follows: 1. *Athyrium filix-femina* (L.) Roth, 2. *Brachypodium sylvaticum* (Huds.) P. Beauv., 3. *Bromus* sp., 4. *Calystegia silvatica* (Kit.) Griseb., 5. *Carex digitata* L., 6. *Carex echinata* Murray, 7. *Cerastium glomeratum* Thuill, 8. *Chenopodium album* L., 9. *Coix lacryma-jobi* L., 10. *Cornus australis* C. A. Mey., 11. *Crataegus microphylla* C. Koch, 12. *Dactylis sanguinalis* (L.) Scop., 13. *Daphne mezereum* L., 14. *Digitaria sanguinalis* (L.) Scop., 15. *Dryopteris borrieri* Newm., 16. *Epipactis* sp., 17. *Eupatorium cannabinum* L., 18. *Fumana procumbens* (Dun.) Gren. & Godron, 19. *Galium odoratum* (L.) Scop., 20. *Geum rivale* L., 21. *Juncus* sp., 22. *Origanum vulgare* L., 23. *Paspalum dilatatum* Poir., 24. *Phragmites australis* (Cav.) Trin. Ex Steud., 25. *Phytolacca americana* L., 26. *Polygonum mite* Schrank., 27. *Potentilla reptans* L., 28. *Pteridium aquilinum* (L.) Kuhn, 29. *Pteris cretica* L., 30. *Rhynchospora maxima*

C. Richter, 31. *Rubus persicus* Boiss., 32. *Ruscus hyrcanus* Woron., 33. *Sambucus ebulus* L., 34. *Sanicula europaea* L., 35. *Scabiosa micrantha* Desf., 36. *Scutellaria lateriflora* L., 37. *Setaria viridis* (L.) p.Beau., 38. *Stellaria media* (L.) Cry., 39. *Trifolium repens* L., 40. *Urtica dioica* L., 41. *Valeriana alliariifolia* Vahl., 42. *Vicia crocea* (Desf.) B. Fedtsch., 43. *Vicia sativa* L., 44. *Viola odorata* L. (Table 2).

Among all plant species, *Brachypodium sylvaticum* and *Polygonum mite* had the most frequent distribution in 4 and 6 of 11 stations, respectively (Table 3). Results of this research revealed that plant species distribution in different forests varied in each altitude as was evident from very small or negligible similarity as well as evenness indices amongst stations of 3 forests surveyed (Table 3). Except for stations 1 and 4 of Javaherdeh which showed similar and minimal diversity indices, other stations displayed moderate to high diversity, primarily because of different composition of species (Table 3). However, within each forest, although plant species composition varied with increasing altitude and usually one species dominated in each forest, there were no clearcut ranges between habitats in altitudinal gradients studied here. The highest richness was observed in coastal-lowland and montane habitats (Tables 2 and 3).

Table 2: Occurrence of herbaceous species in different altitudes in three forests located South of the Caspian Sea (Numbers represent species mentioned above)

Coastal level (Lowland)			Lower Montane (+475 m)			Mid-Montane (+1000m)			Upper Montane (+1500 m)		
Javaherdeh	Dalkhani	Tonekabon	Javaherdeh	Dalkhani	Tonekabon	Javaherdeh	Dalkhani	Tonekabon	Javaherdeh	Dalkhani	Tonekabon
10	8	8	10	3	3	6	8	0	11	3	9
2	2	2	1	1	2	1	1	0	7	10	6
3	3	3	8	5	26	5	7		16	12	20
4	6	9	11	11	32	11	26		19	13	22
9	9	11	19			15	30		20	14	26
23	23	21	20			26	33		22	17	31
24	24	23	26			38	38		26	26	36
26	29	24	27				41		31	28	39
28	37	26	30				44		36	34	42
30		37	31						39	39	43
37			38						40	40	
									42	42	
									43	43	

Table 3: Biodiversity indices of plant species in different altitudes of three forests South of the Caspian Sea

Station	Margalef's richness index	Simpson dominance index	Shannon Diversity index	Pielou's Evenness index
J ₁	0.97	0.74	0.60	0.33
J ₂	1.92	0.46	0.69	0.51
J ₃	1.33	0.28	0.58	0.75
J ₄	1.03	0.73	0.65	0.31
D ₁	0.78	0.32	0.28	0.81
D ₂	0.55	0.39	0.38	0.82
D ₃	1.59	0.26	0.64	0.41
D ₄	1.72	0.37	0.10	0.59
T ₁	0.41	0.41	0.28	0.88
T ₂	0.82	0.35	0.28	0.69
T ₄	1.33	0.17	1.70	0.87

The lowest richness was observed in the lower-mountain of Dalkani and lower-mountain to mid-mountain stations of Tonekabon forests. Plants and fungal species richness were greater at Mid-montane to montane habitats. Dominance index was usually greater at lower elevations than higher elevations. In case of fungi, species occurring at 1000 m and 1500 m had the highest and lowest similarity indices, respectively.

Sorenson similarity indices for plant species at the same elevation (different forests) were 0.14, 0 and 0 and for AM fungal spores 0.21, 0.15, 0.53 and 0.43 for Javaherdeh, Dalkhani and Tonekabon forests, respectively. Sorenson similarity indices for plant species at the same forest (different elevations) were 0.14, 0 and 0 and for AM fungal spore numbers 0.15, 0.38 and 0.50 for stations at the coast upto the highland stations, respectively.

Total spore density was the highest at the Lower Montane in Dalkhani Forest (D2) and the lowest at Tonekabon Forest (T2). One *Acaulospora* species and ten fungal species belonging to *Glomus* were identified as follows: *G. aggregatum*, *G. boreale*, *G. etunicatum*, *G. fasciculatum*, *G. fulvum*, *G. macrocarpum*, *G. microaggregatum*, *G. mosseae* and two unidentified species (Table 4). *G. macrocarpum* was found in all stations except J1. *G. microaggregatum* spores occurred only in Javaherdeh and Dalkhani stations. This species and *G. mosseae* were absent from

Tonekabon stations. *G. boreale* was only found in Dalkhani forest. *G. fulvum* (with low relative abundance) and *G. boreale* (with high relative abundance) were found at higher altitudes over 1000 m above sea level (Table 4). Majority of spores of above species were isolated from dominant plant roots belonging to Poaceae family.

AM fungal community composition, although unique to each rhizosphere, showed great variation between stations and amongst forests as was for the plant species (Table 4). Mid-montane and montane stations showed the highest abundance of fungal species.

Species richness in each forest and within each elevation varied (Table 5). Ecological biometrics of forests indicated that Margalef's index of richness was greater in Javaherdeh forest and other indices were greater in Dalkhani forest. Tonekabon forest showed variable indices but generally, smaller than indices of other two forests (Table 5). Similar pattern held true for AM fungal species distribution.

Results showed Shannon as well as Simpson diversity indices for fungi generally followed the same pattern for plants. Pielou's evenness indices of fungal species did not vary significantly but differed within stations in each forest (Table 5).

Soil type for all stations was sandy loam except for J₁₅₀₀ and T₅₀₀ and T₁₅₀₀ which were clay loam. pH ranged between 7.00 in J₁₀₀₀ to 7.75 at T₁₅₀₀.

Greatest EC was measured at T₁₅₀₀ (65µs/cm) and the lowest at D₁₀₀₀ and J₁₀₀₀ (26 µs/cm). There was no strong correlation between fungal density and

soil elements as well as pH and EC, except with contents of Na and clay at lower elevations which correlated negatively with (Table 6).

Table 4: Relative abundance of AMF species in the rhizospheres of herbaceous plants at different altitudes of three forests South of the Caspian Sea

Altitude above Sea level (m)	Coastal-Lowland			Lower Montane			Mid-Montane			Mountain		Count
	J	D	T	J	D	T	J	D	J	D	T	
<i>Acaulospora sp.</i>	39.70		40			37.14		14.38				4
<i>Glomus aggregatum</i>		24.61	3.64	14.21	12.67	11.43					9.39	6
<i>G.boroale</i>								10.27		93.1		2
<i>G.etunicatum</i>	22.70	13.84	3.64		14.93	14.28		23.29	13.69		29.36	8
<i>G.fasciculatum</i>	9.44		10.9			20	6.55	2.05	12.33			6
<i>G.fulvum</i>							3.57	3.42	3.65			3
<i>G.macrocarpum</i>		15.38	20	32.63	33.03	17.14	43.45	19.86	25.57		24.90	9
<i>G.microaggregatum</i>	7.22	6.15		18.42	16.24		7.14	5.48	10.5	3.9		8
<i>G.mosseae</i>		3.07							6.85	1.95		3
<i>Glomus sp1.</i>	20.50	20	9.09	32.1	17.65		8.33	21.23	7.76		19.12	9
<i>Glomus sp2.</i>		16.92	12.73		6.79		30.95		19.63		16.50	6
Count	5	7	7	4	6	5	6	8	8	3	5	64

Table 5: Spore counts and biodiversity indexes of fungi species

Station	Spore density	Margalef's richness index	Simpson dominance index	Shannon diversity index	Pielou's evenness index
J ₁	45.3±3.1	1.31	0.23	1.52	0.85
J ₂	95.3±2.1	1.10	0.22	1.61	0.90
J ₃	167.6±4.1	0.98	0.30	1.41	0.79
J ₄	176.6±3.1	1.30	0.16	1.94	0.93
D ₁	64.0±3.6	1.44	0.13	1.8	0.93
D ₂	221.0±5.5	1.11	0.19	1.79	0.92
D ₃₀	145.6±2.1	1.40	0.17	1.86	0.89
D ₄₀	205.0±6.2	1.69	0.16	1.97	0.86
T ₁	55.0±4.36	1.50	0.22	1.65	0.85
T ₂	34.6±3.05	1.12	0.22	1.52	0.94
T ₄	121.3±7.0	1.06	0.19	1.71	0.95

Table 6: Metal Oxides in soil of different altitudes in three forests South of the Caspian Sea

Station	L.O.I	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃
J ₁	12.7	1.6	4.0	14.6	53.9	0.2	2.5	3.5	0.7	6.2
D ₁	6.2	1.2	5.9	8.1	60.6	0.2	0.9	8.2	1.0	7.7
T ₁	23	1.7	3.8	11.7	45.6	0.2	1.5	6.7	0.7	5.1
J ₂	13.4	1.0	8.3	12.3	48.5	0.2	1.1	6.2	0.7	8.3
D ₂	45.6	-	13.0	6.1	18.0	0.3	0.5	13.7	0.2	2.5
T ₂	30.3	0.6	1.94	10.3	47.4	0.4	1.3	1.7	0.8	5.1
J ₃	24.3	0.5	1.5	13.0	51.0	0.5	1.3	1.0	0.8	6.0
D ₃	42.0	0.6	1.3	9.2	40.1	0.3	1.2	1.0	0.6	3.4
J ₄	10	0.6	1.7	16.8	60.5	0.1	1.5	0.6	1.0	7.0
D ₄	27	0.6	2.6	12.5	47.3	0.2	1.3	2.2	0.7	5.5
T ₄	9.2	1.2	1.3	15.5	63.5	0.1	2.2	0.8	0.1	5.4

4. Discussion

This investigation examined the relationships between data of AM fungal spore frequency associated with understory herbaceous and shrub species and elevation as well as soil characteristics of three coastal Caspian forests. Herbaceous plants are usually more reactive than many woody species to habitat differences particularly that relating to soil factors and therefore, can be useful indicator species for environmental assessment and monitoring (Wilson et al., 2001). Moreover, because of their differing ecological requirements, understory plants can provide a reliable, relatively quick and easy assessment of site characteristics (Wang, 2000, Naqinezhad, et. al., 2012). In this context, although studies of the relationships between vegetation and soil characteristics have proved particularly useful (Turner and Kelly, 1981; Wang, 1995), not much effort has been placed in analyzing mycorrhizal population data.

Naqinezhad, et. al (2012) reported that *Fagetum* communities in the Caspian forests were confined to soils with high amounts of N, P and organic matter (OM) and sand. They concluded that understory vegetation of these forests appeared to show genuine edaphic restriction to lower N, P and OM to the degree that these three soil variables were important determinants of the distribution of plants in the Hyrcanian (Caspian) area. Eshaghi Rad et al. (2009) also in their earlier studies had concluded that N, P and OM were important factors delimiting ecological species groups. In addition, Mataji, et al. (2010) considered amounts of P, K, OM and soil pH to be important variables determining the species composition of understory vegetation. Common denominator of studies of Naqinezhad, et al. (2012), Eshaghi Rad et al. (2009) and Mataji et al. (2010) is the emphasis on the importance of soil N and P content as well as soil texture, either in the form of sand content or the content of OM. These authors

have paid particular attention to abiotic soil factors and have not considered the important biotic variables of the rhizosphere, for example, the mycorrhizal fungi. It is well documented that ectomycorrhizal fungi form symbiosis with forest trees and AM fungi colonize roots of herbaceous plants (Zare-maivan, 2013). It is also well noticed that content of P in the rhizosphere affects mycorrhizal occurrence negatively, as mycorrhizal symbiosis is primarily established to facilitate nutrient uptake, particularly P uptake under P deficiency of the soil.

As there was no strong correlation between AMF spore density and dominant soil characteristics (pH, EC, soil elements), nor all plant species occurred in all stations in all forests, it was concluded other characteristics of the habitat such as elevation from the sea level, soil texture (type, moisture and oxygen content), temperature and the stage of forest succession might be determining factors. This finding corroborates findings of Naqinezhad, et al, (2012) in which occurrence of plant species was reported to be dependent on the soil texture (contents of sand, clay and silt). Tonekabon forests with higher content of clay and consequently higher moisture and lower oxygen trapped in their particles, had lower fungal spore density compared to other forests at corresponding elevations. Fungal spores isolated from rhizosphere of plants closer to seashore were low in density and correlated negatively with Na ions which inhibits spore germination (Wilde et al., 2009) and causes ion toxicity and ion imbalance in the fungal mycellium (Maas, 1986).

Usually, in phytosociological studies there is a tendency to identify indicator species, and as such species with specific needs and limited niches serve the purpose the most. Although AM fungi have different abilities to associate with roots of mycorrhizal forming plants (Schenck and Kinlock 1980; Johnson et al., 1991), majority of them, however do not appear to be host specific. Hence, in this study, occurrence of fungal species was not

restricted to special plant species. *Glomus* species have been found in many geographic regions with wide ranges of soil and environmental factors (Gopal et al. 2005; D'Souza and Rodriguez, 2012). In this investigation, *G. macrocarpum* was found in 9 of 11 stations, a species well adapted to wide environmental conditions from near moist seashore habitat to soil with high contents of clay in Tonekabon forest. However, specific and detailed investigation is required to establish mycorrhizal forming ability of *Glomus* species such as *G. macrocarpum* with near shore plants (e. g. *Phragmites australis* (Cav.) Trin. Ex Steud) and *Brachypodium sylvaticum* (Huds.) P. Beauv. which commonly occurred in about 70% of the stations.

It was hard to distinguish which environmental factor had the major effect on vegetation and fungi distribution as many environmental variables differed along altitudinal gradients. This finding corroborates findings of Austin et al., (1996). For example, although, J1, D3 and T1 were habitats with 50-70% steep slope, species diversity and richness indices indicated no effect of slope. However, species richness index was lower in coastal-lowland stations (J1, D1 and T1) as these habitats were favorable to only some specific plant species tolerant of excessive moisture or salinity.

Species richness is a criteria usually dependant on many factors that affect plant productivity; for example, inter-species competition, climate change and human activity (Criddle et al., 2003; Hua, 2008). Species richness and diversity indices of stations upto lower montane (1000 m above sea level) were low as these stations were moderately disturbed by human activity and pre-exposed by animal grazing, rendering already vulnerable and disturbance sensitive plant communities of high altitudes (Curtin, 1995) to further stress.

In conclusion, we established the occurrence of mycorrhizal fungal community in herbaceous understory vegetation in three Caspian forests in

central Alborz mountains, emphasizing the importance of soil texture, cation exchange capacity and elevation from sea level in plant community development. Detailed research on specific symbiotic relationships between plant and fungal species is needed to establish detailed criteria necessary for restoration of disturbed ecosystems.

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