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The relationships between some soil characteristics and abundance of arbuscular mycorrhizal fungi spores

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Abstract

Arbuscularmycorrhizae (AM) are important for plant growth and nutrition since they increase mineral influx. Mycorrhizal association plays a key role in the sustainability of terrestrial plant ecosystems, in particular those presenting limitations for the establishment and subsequent growth of plants. However, symbiosis efficiency is affected by many environmental factors. Studies conducted on the number of mycorrhizae in volcanic soils are very limited around the world and there are not any studies conducted in Iran. For this purpose, a study was carried out on soils with volcanic material in northwest of Iran. In this study, 21 horizons were defined in four different profiles with andesitic parent material. The total number of mycorrhizae existing in the horizons determined in a total of 4 profiles, that two of them located in pasture and two in garden areas. It was found out that the number of spores in garden areas was more than the number of spores in pastures. This was attributed to the fact that the existence of plant roots in garden areas was higher compared to pastures. In each profile, the highest number of mycorrhizal spores was obtained from different depths of horizon A, where ventilation is high, and the number of mycorrhizal spores showed a decrease as the depth increased. The correlation carried out in the study also revealed a negative relationship between the number of spores and horizon depth for all values and a positive relationship between the number of spores and organic matter.

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Introduction

Mycorrhizas, which are associations between plant roots and soil fungi, help plants to improve their ability to absorb nutrients in a low soil fertility condition (Berendse and Elberse, 1990; Alexander *et al.* 1992). Smith and Read (1997) estimated that about 80% of plant species form associations with arbuscularmycorrhizal fungi. Mycorrhizal associations with roots of host plants are essential for recovery and stabilization of plant communities (Pankow*et al.* 1991). Sources of AMF inoculum may comprise spores, hyphae and fragments of colonized roots (Janos, 1992). Losses of AM propagules as a result of soil disturbances have been documented (Janos, 1988; McGee, 1989). Such losses resulted in low infectivity rate and hence limit the establishment of vegetation in an area (Sylvia, 1990). Improved P and Zn uptake, particularly in marginal soils, due to AMF colonization have also been well documented (Smith and Read, 1997). Host plant roots colonization by AMF protects roots from infection by pathogens and nematodes (Azcon-Aguilar and Johnson *et al.* 1996) and increases moisture absorption (Graham, 2001). Furthermore, AM mycelium may assist stable soil aggregates forming (Rillig, 2004). Thus, AMF are ecologically important as a part of the soil biota, especially in maintaining interactions between plants and other soil communities. Mycorrhizal fungi are in general more specific to soil type than to host type. Various soil conditions and factors can affect mycorrhizal spore numbers in soils. Soil pH is the major selective factor, but soil texture and organic matter may also influence the suitability of the soil for particular fungi. There are fungi that tolerate cool spring temperatures and others that remain dormant until the soil warms up (Smith *et al*, 1986). AMF symbiosis is thought to play a particularly important role in the successional process on bare or disturbed lands such as volcanic deserts, where the availability of nutrients such as nitrogen and phosphorus is quite limited. According to an AMF-related basic model of primary vegetational succession on volcanic substrates, non-mycotrophic plants are the dominant colonizing species during early successional stages, then facultative mycotrophic species could stablish at the intermediate stages, whereas obligate mycotrophic species may dominate seral communities (Titus and del Moral, 1998; Allen, 1991). Studies on the distribution and infection rates of mycorrhizal spores in volcanic areas around the world and also studies on determining the types of spores are gaining importance each passing day. However, there are no studies on mycorrhizae existing in volcanic areas in Iran. The present study aims to conduct a spore count in four different volcanic sites in Central Anatolia and provide a general contribution regarding the mycorrhizal state of these particular areas.

Material and methods

Description of study area

This study was conducted on pedimonets of Sahand Mountain that located in Azarbaijan - e - sharghi province of Iran, from 46° 28´ to 46° 14´ E longitude and 37° 56´ to 38° 17´ N latitude. We selected four profiles ranging in elevation of 1400-2500 m from sea level. The mean annual rainfall is 380mm and the mean annual temperature is 11°C, soil moisture and temperature regimes are xeric and mesic, respectively. The volcano was mapped tuff and andesite

Sampling and Analysis

Samples were taken from the horizons of four profiles. Soil samples were dried, gently crushed with a wooden roller and sieved to 2 mm. visible roots, stubble, and coarse fragments were removed and stored in plastic bags for use. Soil pH was measured both in a 1:2.5 soil-water suspension and 0.01 N KCl, Electrical conductivity (EC) was determined in a 1:2.5 soil-water suspension (Soil Survay Staff, 2004). Particle size distribution was determined by the hydrometer method after removal of organic matter using H_2O_2 and stirring in a sodium hexametaphosphate solution (Bouyoucos, 1951). Organic matter (OM) in the soils was determined using the Walkley and Black wet digestion method, Alkaline-earth carbonates were measured by acid neutralization and back titration (Nelson, 1982). Cation exchange capacity was obtained by saturation with 1M NH_4OAC at pH 8.2 (Chapman, 1965). Phosphate retention capacity was measured according to the methods of the Soil Survey Laboratory Methods Manual(Soil Survay Staff, 2004). Total P_2O_5 analysis of the soil and rock samples was conducted by fusion with lithium metaborate ($LiBO_2$) and dilution in a HNO_3-HF procedure (Chao and Sanzolone, 1992).

Spore extraction and quantification

After sampling (3 subsamples for each horizon), each soil sample (10 g fresh mass) was sieved according to the sieving and decanting procedure of Gerdeman and Nicolson (1963) and AMF spores were isolated by sucrose gradient centrifugation (Jenkins, 1964), and were then counted (Sylvia, 1994).

Statistical Analysis

Pearson's Correlation Coefficient (r) between analyzed characters was calculated by the SPSS statistical program.

Results and discussion

Site characteristics of studied profiles are presented in table 1. As indicated in the table, 2 profiles are located in garden and 2 profiles are located in pasture land use.

Table 1. Some characteristics of studied profiles.

Profile	Parent material	Elevation(m)	Land use	Land position
1	Andesitic	2020	Garden	Hillslope
2	Andesitic	1838	Garden	Steep slope
3	Andesitic	1589	Pasture	Steep slope
4	Andesitic	1362	Pasture	footslope

As shown in table 2, the soil composition included a pH range of 5.08-7 (light acidic in pH), EC 1.3-41 ds/m, organic matter 0- 5.9%, $CaCO_3$ 0- 0.7% and soils contained 21-55% clay. Their phosphorus fixation capacity rate varied 6- 42.5%. Furthermore, spore numbers varied from 0 to 28 per 10 g of soil samples. As it can be seen in table 2, pH, EC, organic matter, $CaCO_3$, rate of phosphorus retention, percent of clay and mycorrhrizalspores number varied depending on one another and depth in total of 21 horizons in four different profiles. The highest total mycorrhizal spore numbers (64) was found in profile 2, which belongs to a garden land use and has six different horizons. In this profile, the highest mycorrhizal spore number (25 spores/10 g soil) was determined in A2 horizon and in contrast to other profiles, high spore abundance were also observed in the B horizons. In profile 1, where the second highest spore number was observed, a total of 51 spores and spore numbers showed a decrease as the depth increase starting from A horizon.

Regarding the spore numbers in other profiles, there were a total of 28 and 29 sporesin profiles 3 and 4, respectively. The effect of depth on the distribution of mycorrhizal spores in the profile 2 and profile 4 is significant in that it is related to plant root region, because mycorrhizal spores can only survive by hooking into the root of another plant (Harley, 1989; Kendrick, 1985). For this reason, the gradual decrease in spore density that generally occurs through deeper horizons can be attributed to the distance from the plant root and consequently from organic matter and the decrease in air and water. In general, the organic matter simulate spore production, and the mycorrhizal root debris can also be an important reservoirs of inoculum and the contact between colonized root debris and uninfected plant may enhanced the mycorrhizalspead with low annual rainfall (Jeffries and Dodds, 1991).

The correlation analysis (Table 3) showed a negative correlation between mycorrhizal spore number and soil depth in all horizons of four different profiles, but a positive correlation was observed between spore number and organic matter. Of these findings the correlation values regarding the organic matter in profiles 2 and 4 were found to be significant (p<0.01). Anderson *et al.* (1984) also obtained similar correlation between mycorrhizal spore number and organic matter. In addition positive correlation was observed among mycorrhizal spore number and $CaCO_3$ in all horizons.

Table 2. Some physical, chemical and biological properties of studied profiles.

Profile	Horizon	Depth (cm)	pH	EC(ds/m)	Clay (%)	OM(%)	$CaCO_3$(%)	PRetention (%)	CEC (Cmol+/Kg)	Spore number[a]
1	A_1	0-5	6.9	6.5	25	3.9	0.6	17.2	23	13
	A_2	5-15	6.8	3.7	34	1.9	0.3	20	17	28
	AC	15-25	6.7	3.1	37	1.5	0.4	26	22	8
	C	25-50	7	3	26	0	0	23	27	2
2	A_1	0-15	6.3	6.7	21	1	0.4	11	20	23
	A_2	15-35	6.38	2.1	22	0.7	0.2	14.8	16	25
	Bw_1	35-70	6.27	2	22	0.1	0.3	16.1	18	4
	Bw_2	70-100	6.33	1.3	23	0.2	0	15.3	22	8
	C_1	100-120	6.45	2.1	27	0	0	14.2	26	0
	C_2	120-150	6.17	2.6	23	0	0	16	20	4
3	A_1	0-15	6.54	4.3	23	2.7	0.4	6	23	7
	A_2	15-30	6.44	2.8	21	2.1	0.7	7.8	20	21
	Bw	30-50	6.31	3	26	0.6	0	9.9	25	0
	C	50-100	6.8	2.2	24	0	0	9.4	26	0
4	Ah	0-15	6.1	7.6	42	5.9	0.3	21.5	28	13
	A	15-40	6.08	5.5	49	3	0.2	29	25	14
	Bw_1	40-52	5.9	2.9	50	0.44	0.2	40.5	28	0
	Bw_2	52-80	5.7	1.9	42	0.23	0.2	39.2	27	2
	C_1	80-100	5.08	2.9	55	0.26	0	42.7	29	0
	C_2	100-105	4.18	41	27	0	0	35	25	0
	C_3	105-150	4.7	32	51	0	0	34.1	29	0

[a] Data are the means of three replicates.

In conclusion, in this study it was determined that mycorrhizae, which can be naturally found in the soil under all conditions and is a microbiological fertilizer, can also be found at different depth of volcanic areas but their densities could vary depending on various factors existing in that medium, particularly depth and organic matter. Although AMF are widely distributed in nature, there is little information available about the volcanic areas that affect AMF distribution and population. For this reason, more work is needed on the ecology of AMF and their distribution in various volcanic soil conditions.

Table 3. Correlation coefficient of Mycorrhizal spore number and some other soil properties.

Soil properties	Number of mycorrhizal spores			
	Profile1	Profile2	Profile3	Profile4
depth	-0.662	-0.893*	-0.576	-0.755*
pH	-0.383	0.324	-0.261	0.672
EC	0.202	0.520	0.107	-0.336
Clay	0.352	-0.528	-0.906	0.020
OM	0.426	0.951**	0.673	0.903**
$CaCo_3$	0.339	0.619	0.970*	0.696
P retention	-0.485	-0.652	-0.495	-0.839*
CEC	-0.946*	-0.487	-0.980	-0.354

* Significant at 0.05 level. ** Significant at 0.01 level.

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