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SOIL CHEMICAL HETEROGENEITY MAY AFFECT THE DIVERSITY OF ARBUSCULAR-MYCORRHIZAL FUNGI IN THE RHIZOSPHERE OF *TAMARIX APHYLLA* UNDER ARID CLIMATE

Muhammad Shafiq CHAUDHRY[1], Madiha SAEED[1], Faiz-ul-Hassan NASIM[2]

Abstract: The diversity of arbuscular-mycorrhizal fungi associated with *Tamarix aphylla* and the edaphic factors influencing the population patterns of arbuscular mycorrhizae were investigated at Baghdad Campus, Islamia University of Bahawalpur. Highly variable diversity index in arbuscular-mycorrhizal spore densities and their spatial distribution and soil chemical composition was detected. Six genera were identified, among which *Glomus* was the most frequent with 24 species, followed by *Acaulospora* with five species, *Pacispora, Sclerocystis* and *Scutellospora* with two species each and *Entrophosphora* with one species. *Glomus microaggregatum* and *G. glomerulatum* were the most leading species density wise and *G. deserticola* was the most common arbuscular-mycorrhiza species found at all the studied sites. Overall, spore densities were low which is usual for arid lands. Cleared and stained roots displayed the presence of vesicles, resting spores, dichotomously branched arbuscules and extrametrical hyphae. The root colonization status of arbuscular-mycorrhiza was highly variable even in the rhizosphere of same plant, ranging from 46 to 72%. Arbuscular mycorrhizal root colonization and spore distribution patterns in plant rhizosphere seemed also to be affected by edaphic factors, especially salinity and available phosphorus content. It was concluded that the native arbuscular mycorrhizae associated with *T. aphylla* are highly diverse and may have role in the establishment of vegetation in harsh desert conditions through enhancing resource allocation and salinity tolerance.
Keywords: *Tamarix aphylla*, halophyte, arid environment, arbuscular mycorrhizal status, edaphic factors.

Introduction

Tamarix aphylla (L.) Karsten, an important halophytic evergreen tree species of *Tamaricaceae* family (locally known as farash), is found commonly on saline patches of Cholistan desert. Increasing demand of this plant in apiculture, cosmetology, leather industries, erosion control, timber industry and growth on recurring drought affected and saline lands make it highly valuable (Orwa et al., 2009). *Tamarix* is native to southeastern part of Cholistan desert of Asia, which is characterized by sand dunes, sandy hummocks, low organic content, high temperature, low and erratic annual rainfall, strong summer dust storms and generally experience water deficiency during the growth period (Table 1).

In semi-arid areas like Pakistan, concentration of salts and lack of water are enough to damage the growth of this plant. Moreover, harsh climatic conditions make the environment of this area a very tough one for the establishment of vegetation cover (Ali et al., 2009). Salinity, scarcity of water and physico-chemical composition of soil are worldwide problems that affect the establishment of plants in billions of hectares of earth land (Giri and Chamola, 1999). The plants in such harsh environment adopt a wide variety of special features including deep and branched root systems, scaly leaves with thick cuticle and waxy layer on the epidermis and most importantly the development of arbuscular

[1] Department of Life Sciences, Faculty of Science, The Islamia University of Bahawalpur, Pakistan; cids_2005@hotmail.com (corresponding author)
[2] Department of Biochemistry & Biotechnology, Faculty of Science, The Islamia University of Bahawalpur, Pakistan

mycorrhizal fungi that allow them to cope with the desert environment and tolerate stress conditions (particularly salt stress).

Table 1. Uses and medicinal value of *Tamarix aphylla*

Morphology	Botanical name/ Synonyms	Family	Local name	Use/ Medicinal value
A moderate sized evergreen tree, with erect tapering trunk, purplish brown smooth branches; deep extensive root system; leaves bluish green, alternate with epidermal salt glands; flowers stalkless, whitish pink, in racemes 3-6 mm long, drooping; fruit capsule.	*Tamarix aphylla* (L.) Karsten *T. articulata,* Vahl nom. illegit. *T. orientalis* Forsskal	Tamaricaceae	Farash	Flower galls are used as astringent and gargle, bark is used for treating eczema and other skin diseases, honey is dark brown with minty aroma, wood is used as fiber, timber and fuel source, leaves as forage of livestock, galls and bark as mordant for dyeing, tree is highly valuable for stabilizing sand dunes and erosion control.

Arbuscular mycorrhizae are perhaps the most common symbiotic associations with majority of the land plants, and are probably among the most important because they facilitate plant's uptake of phosphorus, which is a limiting nutrient in most of the soils (Yao et al., 2001; Koide and Schreiner, 1992) and also useful in plant species lacking morphological or physiological mechanism for phosphorus uptake (Manjunath and Habte, 1992). Beside its role in enhancing nutrient uptake, arbuscular mycorrhizae also contribute to the plant health and productivity by the suppression of plant diseases (Khaosaad et al., 2007), controlling nematode infection (Elsen et al., 2008), stimulation of phytohormone production (Martínez-Medina et al., 2011), improve soil structure (Wu et al., 2008) and plant tolerance to stress conditions including drought (Pinior et al., 2005) and salinity (Hajiboland et al., 2010). The diversity and distribution of arbuscular mycorrhiza is greatly affected both by biotic and abiotic factors (Mohammad et al., 2003). Panwar and Tarafdar (2006) reported that the association of arbuscular mycorrhizae with plant species native to the harsh environmental conditions may play a significant role in the re-establishment and conservation of endangered plants. Similarly Panwar and Vyas (2002) indicated the significance of arbuscular mycorrhizae in restoration of stress affected vegetation in dry habitats. Many organizations who are concerned with the management of native flora, restoration of natural habitats and production of economically important agricultural and horticultural plants with minimal chemical inputs are interested in the use of arbuscular-mycorrhizal biofertilizer technology. Generally, the knowledge about restoration of salt affected ecosystems by arbuscular mycorrhizae is not too vast and required to undertake more plant re-establishment programmes through mycorrhizae.

Before the exploration of arbuscular mycorrhizal biofertilizer potential related to halophytic plants, it is necessary to investigate the spatial distribution and colonization of arbuscular mycorrhiza in the soil, because it varied with the ecosystems (Hart and Klironomos, 2003) and are affected by the edaphic factors (Sanders, 1990).

For this purpose, an extensive investigation was carried out to assess the spatial distribution and colonization status of arbuscular-mycorrhizal fungi in the rhizosphere of a halophyte *T. aphylla* and repercussion of edaphic factors on the populations of arbuscular-mycorrhiza in the rhizosphere.

Materials and methods

Site Description

Baghdad Campus is located on the fringe of Cholistan desert (28°15'0" N Lat. and 70°45'0" E Long.), which covers two third area of Bahawalpur district (about 15,000 km^2). The Campus presents a picture of a mini-desert. It is characterized by the scarcity of water and low precipitation. The mean annual temperature is 25°C occasionally surpassing 47°C (Kahlown, 2004) and the average annual rainfall is only 120 mm. The vegetation is mainly xeric type. An extensive survey was undertaken and samples were collected from 8 edaphically different locations.

Soil and Root Sampling

Prior to sampling the upper layer of soil was scrapped off to remove litter and plant material. Rhizospheric soil and roots were collected from six to eight centimeters of depth from each site. Five root and soil samples were collected from each eight sites during March 2012. The root and soil samples were placed in polyethylene bags after collection. In laboratory roots were washed immediately with tape water, fixed in alcohol-formalin-acetic (90:5:5 ratio) and refrigerated at 4°C on arrival. The soil samples collected from the sites were homogenized and sieved with two millimeter mesh sized sieve to remove roots and stones. The samples were then air dried and used for trap culturing and estimation of physico-chemical properties of soil. Soil samples were deposited to Soil and Water Testing Laboratories, Regional Office, Bahawalpur, for physico-chemical analysis.

Trap Cultures

Trap culturing is an important tool to induce sporulation of arbuscular mycorrhizal fungi in the soil samples collected from arid ecosystems and facilitates in the detection of arbuscular-mycorrhizal species present in the rhizospheric soil but not sporulate at the time of sampling in the field (Stutz and Morton, 1996). For trap culture, from each sample 400g of field soil was mixed with equal amount of autoclaved river sand (i.e. 1:1 ratio) and placed in a plastic container of 1000g capacity. Then each container was planted with surface sterilized stubs (by 1.0% (w/v) sodium hypochlorite for three minutes and rinsed thoroughly with distilled water) of *Vetiveria zizanioides* as host species. The nurse plants were fed with periodic additions of Hoagland's solution as nutrient media, with P concentration adjusted to 8 mg l^{-1}.

Processing and Estimation of Root Colonization Percentage

To determine the root colonization percentage, refrigerated root samples (fixed in formalin-acetic-alcohol) were washed thoroughly. The roots were cut in two centimeter pieces, placed in 10% KOH and autoclaved for 15 minutes at 121°C. Then roots were washed after removing form potassium hydroxide and darker roots were bleached with alkaline hydrogen peroxide (0.5% NH_4OH and 0.5% H_2O_2 v/v in water) for 20 minutes, after which the roots were rinsed with 3-4 changes of tap water, acidified by treating them with 1N HCl for 3 minutes and washed again. The roots were transferred to 0.05% trypan

blue in lactoglycerol and kept overnight at room temperature. The extent of colonization for each sample was assessed by the method of Trouvelot et al. (1986). 100 randomly selected fine root segments of 1cm length from each replication were mounted in lactoglycerol on a glass slide and examined microscopically. The segment was counted as infected, if any hyphae, vesicles or arbuscules were encountered. The percentages for hyphae, arbuscules, vesicles and intra-radical spores were calculated.

Arbuscular mycorrhizal Spore Extraction

Wet sieving and decanting technique of Gerdemann and Nicolson (1963) was used for the extraction of spores from field and trap culture soils. The arbuscular-mycorrhizal spore density was estimated as number of spores per 100g of soil by the method of Gaur and Adholeya (1994). The arbuscular-mycorrhizal spores were picked up with wooden dowel under a stereo microscope and mounted in PVLG and Meltzer's reagent separately. All the spores were examined using Labomed Digi-2 USA-Research microscope. The identitfication of the arbuscular-mycorrhizal isolates was established by means of spore size and color; surface texture and ornamentation; attachment of subtending hypha and spore wall configuration by using the identification manual of Schenck and Perez (1990) and the description provided by International Collection of Arbuscular Mycorrhiza (*http://invam.caf.wvu.edu*).

Microphotography of Arbuscular-Mycorrhizal Structures and Statistical Analysis

All the microphotographs were taken using Olympus Digi-2 compound microscope fitted with digital camera Digi-1500 coupled with P-IV computer system at the magnification of 40X and 100X.

Microsoft Excel 2007 and Minitab 13 were used in the statistical processing of the data. Pearson correlation among edaphic factors, arbuscular-mycorrhizal spore population and root colonization percentage was deduced using SPSS 16.0.

Results and discussions

During the survey of entire Baghdad campus (15,000 km^2), it was found that *T. aphylla* is a common halophyte and occurred commonly over the area. Edaphic chemical composition of the soil of each sampling site is given in Table 2. Soil texture varies from loam to sandy loam. The soil pH ranged from 7.80 to 8.11, organic carbon content from 0.34 to 0.69% and electrical conductivity from 1.73 to 7.13dSm^{-1}. The soil available phosphorus was from 4.83 to 7.81 ppm and potassium content ranged from 70 to 140 ppm respectively. Saturation percentage varies as the texture of the soil, showing low water holding capacity at the sites having sandy soil. Generally, the soil of Baghdad campus are characterized as alkaline soil with low available P, low organic matter and resultantly low saturation percentage, which in combination with low annual rainfall results in harsh arid conditions leading to increased significance of arbuscular mycorrhizal fungi like biofertilizer technology.

Table 2. Physical and chemical properties of *Tamarix aphylla* rhizospheric soils

Site no.	E.C. (dS/m)	pH	OC (%)	P (ppm)	K (ppm)	SP (%)	Texture
1	3.86±0.03	7.84±0.03	0.45±0.01	6.53±0.03	110.34±12.0	32.66±4.32	Loam
2	7.13±0.03	7.92±0.03	0.66±0.01	4.83±0.03	120.22±46.6	34.32±2.18	Loam
3	3.73±0.06	8.11±0.01	0.69±0.02	6.54±0.02	130.52±31.1	36.67±6.14	Loam
4	6.07±0.03	8.04±0.03	0.52±0.01	7.20±0.01	110.03±15.3	34.26±3.57	Loam
5	4.01±0.01	7.91±0.01	0.66±0.01	7.81±0.01	140.04±24.7	35.13±9.12	Loam
6	2.11±0.01	7.80±0.01	0.34±0.01	6.31±0.03	90.37±14.7	28.00±7.54	Sandy loam
7	1.73±0.02	7.92±0.01	0.34±0.02	5.63±0.02	70.11±22.1	29.01±7.30	Sandy loam
8	3.72±0.03	7.91±0.02	0.45±0.01	6.70±0.01	80.30±31.3	30.33±4.87	Loam

Mean values ± Standard error of means
(E.C. = Electrical conductivity, OC = Organic carbon, P = Available Phosphorus, K = Available Potassium, SP = Saturation percentage)

Thirty six arbuscular mycorrhizal fungal species were identified in the rhizospheric soils collected from the field and successive trap cultures scattered over six genera, *Acaulospora, Entrophosphora, Glomus, Pacispora, Sclerocystis* and *Scutellospora* (Table 3). *Glomus* species were most dominant and account for more than 60 % of the total isolates followed by *Acaulospora* (five species); *Pacispora, Sclerocystis, Scutellospora* (two species each) and *Entrophosphora* (one species). *Glomus glomerulatum* and *Glomus microaggregatum* were the most dominant and *Glomus deserticola* was the most regular encountered arbuscular mycorrhizal specie associated with *T. aphylla* (Table 5). It is evident from the greater number of times *Glomus* is isolated from total number of soil samples compared to other species that *Glomus* is a most copious arbuscular mycorrhizal genus (Table 3) and is obligation rather than exception under arid climate (Tarafdar and Kumar, 1996). This may be due to its high resistance of *Glomus* to elevated soil temperature (Al-Raddad, 1993) and soil salinity (Allen and Cunningham, 1983; Ho, 1987; Wang et al., 2004).

Table 3. Distribution of AMF species per genera, and frequency of occurrence

Genus	No. of species	Relative Abundance	Relative Frequency	Isolation frequency (%)
Acaulospora	5	13.88	13.73	75
Entrophosphora	1	2.77	2.94	37.5
Glomus	24	66.67	65.69	100
Pacispora	2	5.56	5.88	25
Sclerocystis	2	5.56	5.88	50
Scutellospora	2	5.56	5.88	87.5

The viable arbuscular mycorrhizal spore densities recovered from the rhizosphere of *T. aphylla* collected from field or successive trap cultures were ranged between 60 to 246 spores per 100gm soil (Table 4). The arbuscular mycorrhizal fungal isolates were found in all the investigated soil samples but have considerable variation both in number and type of arbuscular mycorrhizal fungal spores at different study sites (Table 5). This reveals a very high arbuscular mycorrhizal fungal diversity in Baghdad campus and a high degree of spatial variance in species composition (Mathur et al., 2007). Overall spore densities were low, which is common for dry habitats (Requena et al., 1996). It is obvious from the results (Table 4) that rhizospheric soil sample collected from site two have higher arbuscular

mycorrhizal spore densities as compared to other sites. This may be due to poor fertility of soil (in terms of low available phosphors) resulting higher arbuscular mycorrhizal spore populations (Norani, 1996).

Table 4. Percent root colonization and AMF spore densities (100 g^{-1} soil) in the rhizosphere of *Tamarix aphylla* at different sites of Baghdad Campus

Site no.	Percent Root Colonization (%)	AMF Spores per 100g. Soil
Site 1	55±2.2	139±6.1
Site 2	71±1.9	246±2.9
Site 3	56±1.8	168±7.4
Site 4	72±2.4	140±6.3
Site 5	46±1.1	80±3.9
Site 6	50±2.9	60±2.2
Site 7	50±1.0	107±1.7
Site 8	50±1.7	94±2.0

Mean values ± Standard error of means

Table 5. Spatial distribution of AMF Spores in the rhizosphere of *Tamarix aphylla* at different sites

AMF species	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8
Acaulospora alpina Oehl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
Acaulospora bireticulata Rothwell & Trappe	0.0	0.0	0.0	6.43	13.7	3.3	1.8	0.0
Acaulospora foveata Trape & Janos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Acaulospora laevis Gerd. & Trappe	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
Acaulospora rehmii Sieverd. & Toro.	0.0	0.0	0.0	12.8	0.0	0.0	0.0	0.0
Entrophosphora infrequens (Hall) Ames & Schneider	0.0	0.0	0.0	0.0	7.5	5.0	1.8	0.0
Glomus aggregatum Schenck & Smith	0.0	0.0	12.5	16.4	0.0	0.0	0.0	0.0
Glomus ambisporum Smith & Schenck	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glomus auraeum Oehl & Sieverd.	0.0	2.8	0.0	0.0	8.7	0.0	0.0	13.8
Glomus badium (Oehl) Redecker & Sieverd.	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.06
Glomus caesaris Sieverd. & Oehl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1
Glomus claridonium Schenck & Smith	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0
Glomus clarum Nicolson & Schenck	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0
Glomus constrictum Trappe	3.6	0.0	0.0	0.0	0.0	0.0	14.0	0.0
Glomus coronatum Giovann.	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Glomus deserticola (Trappe) Bloss & Menge	3.6	2.4	12.5	1.4	6.25	3.3	12.1	8.5
Glomus etunicatum Becker & Gerd.	0.0	4.07	10.7	12.8	2.5	1.6	13.0	0.0
Glomus fasiculatum (Thaxter) Gerd. & Trappe	5.0	2.0	17.2	9.2	11.2	5.0	0.0	0.0
Glomus geosporum (Nicol. & Gerd.) Walker	0.0	0.0	8.33	22.8	0.0	0.0	0.0	3.1

Glomus glomerulatum Sieverd.	39.5	23.9	9.5	7.8	0.0	6.6	19.6	0.0
Glomus intraradices Schenck & Smith	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0
Glomus invermaium Hall.	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glomus macrocarpum Tul. and Tul.	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0
Glomus manihotis (Howler) Sieverd. & Schenck	2.8	0.4	0.0	0.0	0.0	0.0	3.7	0.0
Glomus microaggregatum Koske, Gemma & Olexia	0.0	62.2	0.0	0.0	0.0	41.6	21.5	0.0
Glomus mossae (Nicol. & Gerd.) Gerd. & Trappe	0.0	0.0	6.5	0.0	0.0	23.3	0.0	0.0
Glomus pansihalos Berch & Koske	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9
Glomus sinuosa (Gerd. & Bakshi) Almeida & Schenck	15.8	0.0	0.0	0.0	0.0	6.6	4.6	3.1
Glomus trimurales Koske & Halvorson	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0
Glomus walkeri Blaszk. & Renker.	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0
Pacispora boliviana Sieverd. & Oehl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8
Pacispora robigiana Sieverd. & Oehl	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0
Sclerocystis clavispora Trappe	0.0	0.0	0.0	3.57	33.7	0.0	0.0	0.0
Sclerocystis rubiformis Gerd. & Trappe	2.16	0.81	0.0	0.0	0.0	0.0	0.0	0.0
Scutellospora scutata Walker & Dieder	0.0	0.0	0.0	0.0	0.0	0.0	1.87	3.19
Scutellospora nigra (Redhead) Walker & Sander	*7.9*	*0.0*	*9.5*	*1.4*	*3.7*	*3.3*	*2.8*	*4.2*

[a]Percent values of total spores

Percent root colonization of arbuscular mycorrhizal fungi in *Tamarix aphylla* was also highly variable ranging from 46 to 72% (Table 4) at different sites even in the same season, which may be attributed to the greater heterogeneity in soil chemical composition and varied inoculum potential at different sites of sample collection (Miller, 2000; Brown and Morton, 1996).

Processed and stained root sections showed the presence of subglobose to ellipsoidal and rectangular vesicles, dichotomously branched arbuscules, hyphal cuttings, spore saccules (Fig. 1) and well stained hyphae in all the root samples. Extrametrical hyphae bearing resting spores were also observed in the roots of *T. aphylla* (Mathur et al., 2007).

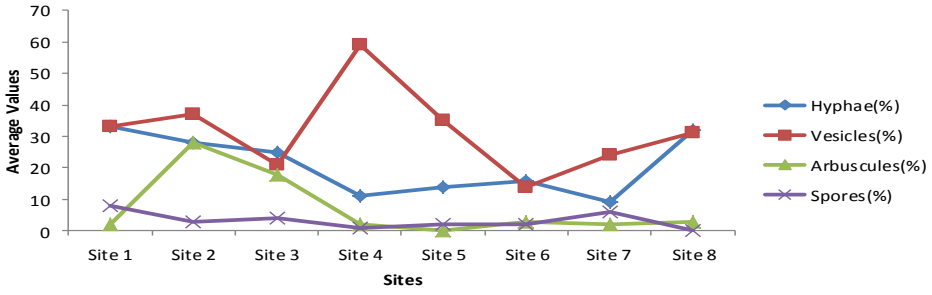

Figure 1. Relative percentage of different AMF variables studied in roots of *T. aphylla* at eight sites

Previous research has shown that salinity reduces arbuscular mycorrhizal fungal colonization in plants by inhibiting the germination of spores (Carvalho et al., 2001; Barrow et al., 1997) but present results are contradictive to this as the figure 2 depicts greater densities and variation of arbuscular mycorrhizal fungal spores at site 2 having significant soil salinity (EC = 7.1 dSm^{-1}), but in line with the findings of Hirrel (1981) Tressler and Hayer (1971), who suggested that sporulation by arbuscular mycorrhizal fungi is stimulated under salt-stress conditions, which means that fungi may produce more spores at lower root colonization levels in severe saline conditions (Aliasgharzadeh, et. al., 2001). Unlike spore density, species richness showed a negative correlation with soil salinity. Species richness decreased as the EC increased at site 2 and increased as the EC decreased at site 7, indicating that saline soils have highly specific arbuscular mycorrhizal fungal consortium.

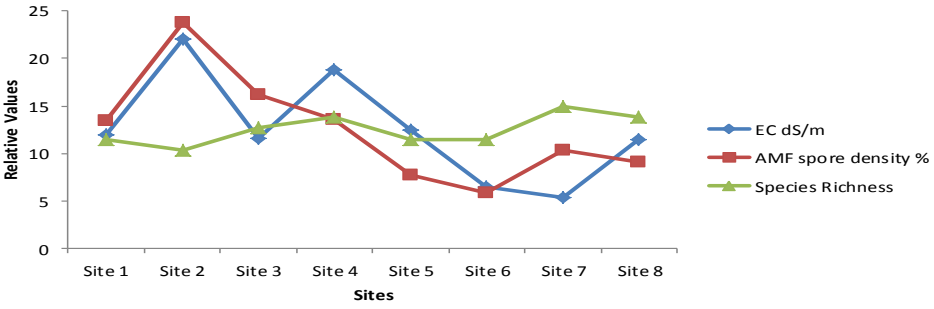

Figure 2. Correlative analysis among salinity extent, AMF spore diversity and species richness associated with *Tamarix aphylla*

The correlative analysis between arbuscular mycorrhizal fungal (AMF) spore populations, root colonization status and edaphic chemical factors of soil have been given in table 6. These reveal that both spore densities and percent root colonization were affected by available phosphorus and electrical conductivity. Arbuscular mycorrhizal fungal spore population and percent root colonization were strongly dependent on each other indicating a significant positive correlation. Increased viable arbuscular mycorrhizal fungal reproductive structures (spore populations) results in more root infection resulting enhanced colonization status, which in result increase the growth and proliferation of roots leading to more arbuscular mycorrhizal fungal spore densities. A significant positive correlation of EC with fungal spore densities (r=.759, $p<.05$) and plant root colonization by arbuscular mycorrhizal fungi (r=.848, $p<.01$) was noted during present investigation. In contrast, increase in soil phosphorus was correlated with a decrease in spore population (r= -.598) and root colonization by arbuscular mycorrhizal fungi (r= -.343). Similar findings were reported by Dhillon and Zak (1993), who stated that when plants have high nutritional status (especially in terms of phosphorus), a negative response by arbuscular mycorrhizal fungal should be expected. No correlation among arbuscular mycorrhizal fungal spore/roots infections status and pH, organic carbon, available potassium and saturation percentage was observed. However, contradictory results were reported by Mathur and Vyas (1997) and Blaszkowski (1993), who observed a significant positive correlation between arbuscular mycorrhizal fungal spore density and soil pH while their investigations. Similarly a positive

correlation with organic carbon content in soil coincides with the findings of Mohammad et al. (2003) under semi-arid environment of Jordan. Organic content in the soil increases water holding capacity of the soil (Brady and Weil, 1996), therefore, may facilitate a favorable soil moisture condition for AMF population. Similar correlation results have been recorded from rhizosphere of *T. aphylla* (r=.937, *p<.01*).

Table 6. Pearson correlation of among chemical factors of soil, percent root colonization and fungal spore percentage

	EC	pH	OC	Available P	Available K	SP	PRC
pH	.341						
OC	.649	.593					
Available P	-.128	.159	.141				
Available K	.529	.381	.889**	.347			
SP	.639	.696	.937**	.266	.894**		
PRC	.848**	.410	.339	-.343	.233	.415	
FSP	.759*	.411	.583	-.598	.377	.569	.774*

(E.C. = Electrical conductivity, OC = Organic carbon, P = Available Phosphorus, K = Available Potassium, SP = Saturation percentage); *p< .05; **p<.01

No arbuscular mycorrhizal fungi have been reported so far from the rhizosphere of *T. aphylla*, except Panwar and Vyas (2002), who reported arbuscular mycorrhizal fungal status of same halophyte in Indian Thar desert. Our results pioneered to identify the status and occurrence of the *T. aphylla* in Baghdad campus as well as arbuscular mycorrhizal fungal diversity associated with it. *Glomus* proved to be the most common arbuscular mycorrhizal genus associated with *T. aphylla*, this is because, *Glomus* spores being smaller in size may have less time to reach maturity as compared to other speceies in short duration of moisture regimes (Tao et al., 2004). Recovery of large arbuscular mycorrhizal fungal diversity from the rhizosphere of this plant reveals the rich wealth of arbuscular mycorrhizal fungi in harsh environmental conditions. These native AMF isolates with a strong strength to survive under water and salt stress conditions may be useful in the re-establishment of the edaphically degraded areas. Artificial inoculation strategy of some of these indigenous arbuscular mycorrhizal fungal species would make the re-establishment and regeneration attempts ecologically and economically more successful in such harsh ecosystems. It is hoped that our findings will provide baseline information for the usage of this technology in the field on a large scale. Further research is required for better understanding of host plant and geographic location specificity of arbuscular mycorrhizal fungi under stress conditions.

Conclusions

1. The rhizosphere of *T. aphylla* had shown a highly diversified arbuscular mycorrhizal fungal consortium with respect to soil chemical composition and AMF spore densities. Six genera were detected among which *Glomus* was the most dominant, which depicts its importance in arid habitats.
3. Arbuscular mycorrhizal fungal root colonization status and spore distribution seemed also to be affected by edaphic factors, especially salinity and available phosphorus content.

arbuscular mycorrhizal fungal association enhances in response to increased salinity and decreased phosphorus content.

3. Arbuscular mycorrhizal fungal colonization of host plant root may have role in the establishment of vegetation in harsh desert conditions through enhancing resource allocation and salinity tolerance.

REFERENCES

Ali, I., Chaudhry, M.S., Farooq, U., 2009. Camel raring in Cholistan Desert of Pakistan. Pakistan Veterinary Journal. **29**, *2*: 84-92.

Aliasgharzadeh, N., Rastin, N.S., Towfighi, H., Alizadeh, A., 2001. Occurrence of arbuscular mycorrhizal fungi in saline soils of the Tabriz Plain of Iran in relation to some physical and chemical properties of soil. Mycorrhiza. **11**: 119-122.

Allen, E.B., Cunningham, G.L., 1983. Effects of vesicular arbuscular mycorrhizae on *Distichlis spicata* under three salinity levels, New Phytologist. **93**: 227-236.

Al-Raddad, A., 1993. Distribution of different *Glomus* species in rainfed areas in Jordan. Dirasat. **20**: 165-182.

Barrow, J. R., Havstad, K. M., McCaslin, B.D., 1997. Fungal root endophytes in four wing saltbrush, *Atriplex canescens*, on arid rangeland of southwestern USA. Arid Soil Research and Rehabilitation. **11**: 177-185.

Blaszkowski, J., 1993. The occurrence of arbuscular fungi and mycorrhizae *Glomales* in plant communities of maritime dunes and shores in Poland. Bulletin of the Polish Academy of Science and Biological Sciences. **41**: 377-392.

Brady, N.C, Weil, R.R., 1996. The Nature and Properties of soils, 11th Edn. Prentice Hall Incorporation, New Jersey, USA: p. 739.

Brown, A.M., Morton, J.B., 1996. Spatial and temporal dynamics of mycorrhizas *Jaumea carnosa*, a tidal saltmarsh halophyte. Journal of Ecology. **84**: 703-715.

Carvalho, L.M., Correia, P.H., Martins-Loucao, A., 2001. Arbuscular mycorrhizal fungal propagulesin a saltmarsh. Mycorrhiza. **14**: 165-170.

Dhillon, S.S., Zak, J.C., 1993. Microbial dynamics in arid ecosystems-desertification and the potential role of mycorrhizas. Revista Chilena De Historia Natural. **66**: 253-270.

Elsen, A., Gervacio, D., Swennen, R., De Waele, D., 2008. AMF-induced biocontrol against plant parasitic nematodes in *Musa* sp.: a systemic effect. Mycorrhiza. **18**, *5*: 251-256.

Gaur, A., Adholeya, A. 1994. Estimation of VAM spores in the soil - a modified method. Mycorrhiza News. **6**: 10-11.

Gerdemann, J.W., Nicolson, T.H., 1963. Spore density of *endogone*species extracted from soil wet sieving and decanting. Transactions of British Mycological Society. **46**: 235-244.

Giri, B., Chamola, B.P., 1999. Vesicular Arbuscular Mycorrhizal Fungi under Salinity and Drought Stress, in Tiwari, J.P., Lakhanpal, T.N., Singh, J., Gupta, R., Chamola, B.P. (Eds.). *Advances in Microbial Biotechnology*, ABH Publishing, New Delhi: p. 421-430.

Hajiboland, R., Aliasgharzadeh, N., Laiegh, S.F., Poschenrieder, C.P., 2010. Colonization with arbuscular mycorrhizal fungi improves salinity tolerance of tomato (*Solanum lycopersicum* L.) plants. Plant and Soil. **331**, *1-2*: 313-327.

Hart, M, M., Klironomos, J.N., 2003. Diversity of Arbuscular Mycorrhizal Fungi and Ecosystem Functioning. Mycorrhizal Ecology. **157**: 225-242.

Hirrel, M.C., 1981. The effect of Sodium and Chloride salts on the germination of *Gigaspora margarita*. Mycologia. **43**: 610-617.

Ho, I., 1987. Vesicular-arbuscular mycorrhizae of halophytic grasses in the Alvord desert of Oregon. Northwest Science. **61**: 148-151.

Kahlown, M.A. 2004. Rainwater harvesting in Cholistan Desert: A case study of Pakistan: p. 155.

Khaosaad. T., Garcia-Garrido, J.M., Steinkellner, S.,Vierheilig, H., 2007. Take-all disease is systemically reduced in roots of mycorrhizal barley plants. Soil Biology and Biochemistry. **39**, *3*: 727-734.

Koide, R.T., Schreiner, R.P., 1992. Regulation of the vesicular-arbuscular mycorrhizal symbiosis. In Annual Review of Plant Physiology and Plant Molecular Biology. **43**, *1*: 557-581.

Manjunath, A., Habte, M., 1992. External and internal P requirements of plant species differing in their mycorrhizal dependency. Arid Soil Restoration and Rehabilitation. **6**: 271-284.

Martinez-Medina, A., Roldan, A., Albacete. A., Pascual, J.A., 2011. The interaction with arbuscular mycorrhizal fungi or *Trichoderma harzianum* alters the shoot hormonal profile in melon plants. Phytochemistry. **72**: 223-229.

Mathur, N., 2007. Arbuscular mycorrhizal status of medicinal halophytes in saline areas of Indian Thar Desert. International Journal of Soil Science. **2**, *2*: 119-127.

Mathur, N., Vyas, A. 1997. Vesicular arbuscular mycorrhizae in Indian Thar desert. Journal of Indian Botanical Society. **76**: 125-126.

Miller, S.P., 2000. Arbuscular mycorrhizal colonization of semi-aquatic grasses along a wide hydrological gradient. New Phytologist. **145**: 145-155.

Mohammad, M.J., Hamad, S.R., Malkawi, H.I., 2003. Population of arbuscular mycorrhizal fungi insemi-aridenvironment of Jordan as influenced by biotic and abiotic factors. Journal of Arid Environment, **53**: 409-417.

Norani, A., 1996. An assessment & enumeration of vesicular arbuscular mycorrhizal propagules in some forest sites of Jengka. Journal of Tropical& Forest Sciences. **9**: 137-146.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., Anthony, S., 2009. Agro-forest tree Database: A reference and selection guide version 4.0 [http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp. [accessed on 28th August 2009].

Panwar, J., Tarafdar, J.C., 2006. Distribution of three endangered medicinal plant species and their colonization with arbuscular mycorrhizal fungi. Journal of Arid Environments. **65**, *3*: 337-350.

Panwar, J., Vyas, A., 2002. AM fungi: A biological approach towards conservation of endangered plants in Thar Desert, Indian Current Science. **82**: 576-578.

Pinior, A., Grunewaldt-Stöcker, G., Alten, H.V., Strasser, R.J., 2005. Mycorrhizal impact on drought stress tolerance of rose plants probed by chlorophyll *a* fluorescence, proline content and visualscoring. Mycorrhiza. **15**, *8*: 596-605.

Requena, N., Jeffries, P., Barera, J.M., 1996. Assessment of natural mycorrhizal potential in a desertifiedemi-arid ecosystem. Applied Environ. Microbiol. **62**: 842-847.

Sanders, I.R., 1990. Seasonal patterns of vesicular-arbuscular mycorrhizal occurrence in grasslands. Symbiosis. **9**: 315-320.

Schenck, N.C., Perez, Y., 1990. Manual for the identification of VA Mycorrhizal Fungi. 3rd Edn. Synergistic Publication, Gainesville. Florida. USA: p. 286.

Stutz, J.C., Morton, J.B., 1996. Successive pot cultures reveal high species richness of arbuscular mycorrhizal fungi in arid ecosystems. Canadian Journal of Botany. **74**: 1883-1889.

Tao, L., Jianping, L., Zhiwei, Z., 2004. Arbuscular mycorrhizas in Valley type Savanna in southwest China. Mycorrhiza. **14**: 623-327.

Tarafdar, J.C., Kumar, P., 1996. The role of vesicular arbuscular mycorrhizal fungi on crop, tree & grasses grown in arid environmental. Journal of Arid Environment. **34**: 197-203.

Tressler, H.D., Hayer, J.A., 1971. Sodium Chloride tolerance of terrestrial fungi. Applied Microbiology. **22**: 210-213.

Trouvelot, A., Kough, J.L., Gianinazzi-Pearson, V., 1986. Mesure du taux de mycorhization VAd'unsysteme radiculaire. Recherche de methodes d'estimation ayant une signification functionnelle, in Gianinazzi-Pearson, V., Gianinnazi, S. (Eds.). Physiological & Genetical Aspects of Mycorrhizae. INRA Press. Paris: p. 217-221.

Wang, F.Y., Liu, R.J., Lin, X.G., Zhou, J.M., 2004. Arbuscular mycorrhizal status of wild plants in saline-alkaline soils of the Yellow River Delta. Mycorrhizae. **14**: 133-137.

Wu, Q.S., Xia, R.X., Zou, Y.N., 2008. Improved soil structure and citrus growth after inoculation withthree arbuscularmycorrhizal fungi under drought stress. European Journal of Soil Biology. **44**, *1*: 122-128.

Yao, Q., Li, X., Feng, G., Christie, P., 2001. Mobilization of sparingly soluble inorganic phosphates by the external mycelium of an abuscular mycorrhizal fungus. Plant and Soil. **230**, *2*: 279-285.