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Mycorrhizas in the Perennial Grasses of Cholistan Desert, Pakistan

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Abstract: Roots of eleven perennial grass species and their associated rhizosphere soil samples were collected from different rangeland habitats of Cholistan desert and studied for the occurrence of symbiotic arbuscular mycorrhizal (AM) associations of Glomalean fungi with their roots and AM fungal propagules in their rhizospheres. *Panicum antidotale* roots showed highest percentage of AMF colonization (i.e., 92.75%) while lowest percentage (43.5%) was recorded in the roots of *Cyprus conglomeratus*. Roots of all the grasses studied had vesicular infection whereas only 27.27% grass species exhibited arbuscular infection. Except *Cenchrus biflorus*, Dark Septate Endophyte (DSE) fungal hyphae were always present concurrently with the AMF hyphae in the cortices of all the root samples of the grass species studied. Average number of AMF propagules recovered from the rhizospheres of the grasses examined in the present study ranged from 19.33 in *Ochthochloa compressa* to 356.32 in *Cenchrus biflorus*. Spores belonging to the *Glomus* sp. such as *G. fasciculatus*, *G. deserticola* and *G. agrigatum* were the dominant ones among the AMF species encountered in this study. Maximum number of AMF species were recovered from the rhizospheres of *Cymbopogon jwarancusa*. The potential significance of AMF in the development of mycorrhiza dependent perennial grasses of Cholistan desert is discussed. Researchers could use this knowledge in the revegetation attempts to put a green mantle on the desertified land and to stabilize sand dunes.

Key words: Arbuscular mycorrhizal fungi, AMF species frequency, cholistan desert, dark septate endophyte, Perennial grasses

INTRODUCTION

The natural vegetation of Cholistan rangelands is typical of arid tract and is composed of mainly the xerophytes. The flora is well adapted to the extreme seasonal temperatures, moisture changes and to the edaphic conditions. The principal adaptation is, however, governed by the availability of moisture and soil chemical composition (Chaudhry and Khan, 2002).

High aridity and brackish subsoil water collectively constraint the usual agricultural practices, therefore, the present land use in Cholistan desert is as natural grazing grounds. The local inhabitants are pastoral nomads and rear large herds of livestock. Since the grazing is open without any control therefore, grasses being the most palatable are the first to suffer from overgrazing leading to habitat deterioration especially during the drought years.

Arbuscular Mycorrhizal Fungi (AMF) are ubiquitous and abundant soil mycoflora and constitute an important functional component of the rhizospheres of 80-90% land plants in natural, agricultural, and forest ecosystems (Brundrett, 2002). They form a fundamental link between

biotic and abiotic components of the soil system (O'Neil *et al.*, 1991). There is an increasing body of evidence suggesting that the distribution and abundance of desert vegetation is influenced by the composition of indigenous microbial communities (Camargo-Ricalde and Dillion, 2003; Chaudhry *et al.*, 2005; Dhillon and Zak, 1993; Tarafdar and Kumar, 1996). Studies over the past few years have demonstrated that arbuscular mycorrhizas (AM) influence several aspects of plant community structure and function by influencing various parameters such as plant diversity, species composition and successional dynamics (Hartnett and Wilson, 2002). Plant species diversity may be positively (van der Heijden *et al.*, 1998) or negatively (O'Connor *et al.*, 2001) correlated with AMF populations. AMF may also alter plant species composition with no net effect on species richness (Smilauer and Smilauerova, 2000), or may alter rates of succession (Smith *et al.*, 1998). AM status of plants and their succession can vary depending on the moisture and nutrient conditions of the soil (Allen and Allen, 1990).

Though there are reports on the arbuscular mycorrhizal (AM) status of plant species from arid and

semiarid regions of the world (e.g., Khan, 1974; Fontenla *et al.*, 2001; Ruotsalainen *et al.*, 2002) but information about the potential significance of mycorrhizae for the restoration of derelict habitats in Pakistan and particularly from Cholistan desert is lacking. Very few studies had been carried out from Cholistan desert of Pakistan (Hameed *et al.*, 1994; Chattha *et al.*, 1993; Chaudhry *et al.*, 2005).

In view of the fact, perennial grasses consist major portion of the Cholistan desert xeric vegetation and play a fundamental role in livestock rearing, the arbuscular mycorrhizal status of eleven perennial grasses of Cholistan desert with high fodder value have been studied. Such mycorrhization studies may be important for the restoration of disturbed habitats and range management programs.

MATERIALS AND METHODS

Sites: Vast sandy desert Cholistan (locally known as Rohi) of today covers an area of more than 26,000 sq km (about 2.69 million hectares), constituting the southern part of Bahawalpur division. It is about 480 km long and 32 to 192 km wide (Akbar *et al.*, 1996). It's climate is sub-tropical continental desert type characterized by extreme temperatures and most of the precipitation occurs between the months of June to September (100-200 mm per annum (Akram, 1993). Relative humidity usually remains low and summer has strong summer winds (Akram *et al.*, 1986; Chaudhry *et al.*, 2005). The region bears above 110,000 humans consisting of 51% males and 49% females (Chaudhry and Khan, 2002). Geomorphologically, the Cholistan desert consists of two natural regions, the Greater Cholistan (13960 km²) and the Lesser Cholistan (12370 Km²). The Greater Cholistan lies to the southwest of the most recent course of the now defunct Hakra River and extends to the border with India. The lesser Cholistan extends north eastwards from the Hakra River to the end against the banks of the Sutlej River (Khan and Chaudhry, 2001).

For the collection of roots and rhizosphere soil samples seven sites were selected within the Cholistan desert. Four sites (i.e., from S1 to S4) were located in the Lesser Cholistan while three sites (i.e., S5 to S7) were chosen in the Grater Cholistan (Table 1). A plot of 100×100 m was marked at each study site. The selection of sites was based on floristic composition (mainly grass species) with variable topography and soil at a particular location.

Sampling: The sampling was carried out during October/November, 2004 at all the study sites within the

Cholistan desert. The roots of ten healthy and green individual's representative of each grass species were carefully dug out when growing at a particular site, placed in polythene bags, sealed, tagged and brought back to the laboratory.

AM colonization assessment: In the laboratory the fine feeder roots from each grass species were separated and mixed to give a single compound sample. Eight sub-samples (each 15 g) for each grass species were washed thoroughly to remove the soil particles. The grass species such as *Cenchrus ciliaris* and *Lasiurus scindicus* that form sand sheath on their roots and had very fragile cortex, were placed overnight in water to dislodge the soil then washed for several times.

The washed root sub-samples were fixed in FAA (Formaldehyde: Acetic acid: Alcohol-5:5:90, V/V) and stored at 4°C till processed for mycorrhization. The roots were washed and cleared in 10% KOH in autoclave at 240°C and 10 psi pressure for 10 min, acidified in 1N HCl for 3-5 min, stained with 0.05% trypan blue in lectophenol as per Phillips and Hayman (1970). The data for the frequency of coiling, vesicles and arbuscules were estimated from randomly picked 100, 1 cm root fragments placed on slides (10 on each slide) in lectophenol while percentages for Dark Septate Endophte fungus (DSE) and mycorrhizal colonization were obtained by gridline intersect method (Giovannetti and Mosse, 1980). Heavily pigmented roots require long bleaching in 20% H₂O₂ and neutralization with 10% HCL prior to staining. For the collection of microscopic and grid line intersect data we use Labomed-Digi-2-USA research microscope and Labomed Digi Star USA, zoom stereoscope fitted with ccd cameras and linked to P-IV computers.

Rhizosphere collection and extraction of AMF propagules: Ten soil samples were collected up to the depth of approximately 30 cm from the root zones of each grass species and stored at 4°C until analyzed for physicochemical characteristics and spore extraction.

At the time of spore extraction ten soil samples, taken for each grass species, collected from different sites (Table 1) were thoroughly mixed and divided into five sub samples of 100 g each. Spores were extracted from the soil by wet sieving and decanting technique (Gerdeman and Nicolson, 1963). Healthy spores of each distinctive morphotype were directly counted under Zoom Stereomicroscope (i.e., DigiStar-2, Labomed, USA) and recorded as mean spores per 100 g.

Trap cultures and identification of AMF species: Open culture was establish in 10×23 cm plastic tubes. This

Table 1: Descriptions of sites for plant species sampling, location and dates of sampling in Cholistan desert. The sampling was carried out during the month of October and November 2004

Site	Location	Date of sample collection	Plant species sampled	Habitat	Type of disturbance
Murad Toba S1	La= 28° 46' N Lo= 71° 37' E	3rd October, 2004	<i>Cyperus conglomeratus</i> , <i>Lasiurus scindicus</i> , <i>Cymbopogon jwarancusa</i> <i>Cyperus rotundus</i> , <i>Cenchrus biflorus</i> , <i>Cenchrus ciliaris</i>	Sandy flat with 3-4 m high dunes on the sides.	Livestock grazing
Kadawala Toba S2	La= 28° 38' N Lo= 71° 59' E	3rd October, 2004	<i>Cymbopogon jwarancusa</i> , <i>Cyperus rotundus</i> , <i>S. ochthocloa compressa</i> <i>Cyperus conglomeratus</i> , <i>Panicum antidotale</i> , <i>Panicum turgidum</i>	Sandy flat with about 30% slope	Livestock grazing
Lalsohanra S3	La= 29° 28' N Lo= 71° 59' E	17th October, 2004	<i>Ochthocloa compressa</i> , <i>Cenchrus biflorus</i> , <i>Cenchrus ciliaris</i> , <i>Sporobolus iocladius</i> , <i>Saccharum bengalense</i> , <i>Panicum turgidum</i>	Small sandy dunes and interdunal sandy flats.	Farming
Darawar Fort S4	La= 28° 45' N Lo= 71° 20' E	25th October, 2004	<i>Panicum antidotale</i> , <i>Cenchrus ciliaris</i> , <i>Panicum turgidum</i> , <i>Cyperus rotundus</i> <i>Cyperus conglomeratus</i> .	Sandy flat	Farming
Bandwala Toba S5	La= 28° 08' N Lo= 72° 54' E	25th October, 2004	<i>Lasiurus scindicus</i> , <i>Saccharum bengalense</i> , <i>Cymbopogon jwarancusa</i> , <i>Cenchrus biflorus</i> . <i>Ochthocloa compressa</i> .	High sandy dunes	Livestock grazing and cutting
Bahuwala Toba S6	La= 28° 07' N Lo= 70° 44' E	5th November, 2004	<i>Cyperus rotundus</i> , <i>Cyperus conglomeratus</i> , <i>Panicum turgidum</i> , <i>Panicum antidotale</i> . <i>Sporobolus iocladius</i>	High shifting sand dunes with large sandy flats	Livestock grazing and wind erosion
Islamgarh S7	La= 27° 52' N Lo= 70° 50' E	5th November, 2004	<i>Lasiurus scindicus</i> , <i>Cyperus rotundus</i> , <i>Cyperus conglomeratus</i> <i>Sporobolus iocladius</i>	Medium height shifting sand dunes	Livestock grazing and wind erosion

Table 2: Arbuscular mycorrhiza in the perennial grasses of Cholistan desert

Grass species	Family	Percent root length colonized		Percent frequency of coiling		Percent frequency of vesicles per 100 cm roots	Percent frequency of arbuscules per 100 cm roots	Average spore number per 100 g soil
		AM	DSE	AM	DSE			
<i>Cyperus conglomeratus</i> Linn.	Cyperaceae	43.5±0.6	64.6±0.2	-	12.0±0.1	40.7±0.3	-	33.6±0.3
<i>Cyperus rotundus</i> Linn.	Cyperaceae	45.7±0.3	54.7 ±0.3	-	19.0±0.4	21.0±0.4	-	198.0 ±0.5
<i>Cymbopogon jwarancusa</i> (Jones) Schult.	Poaceae	65.7±0.5	22.0±0.3	16.0±0.2	6.8± 0.3	51.5±0.4	-	144.6±0.3
<i>Cenchrus biflorus</i> Roxb	Poaceae	78.3±0.3	-	27.75± 0.2	-	43.7±0.6	-	356.3±1.7
<i>Cenchrus ciliaris</i> Linn.	Poaceae	64.7±0.8	2.3±0.2	40.3±0.7	1.5± 0.6	51.1±0.3	14.62±0.59	121.6±0.5
<i>Ochthocloa compressa</i> (Forsskal.) Hilu.	Poaceae	44.5±0.7	81.2±0.3	8.0±0.2	2.0±0.9	23.7±0.6	-	19.3±0.3
<i>Saccharum bengalense</i> Retz.	Poaceae	66.8±0.5	53.2±0.4	31.2±0.5	51.0±0.0	66.2±0.5	15.87±0.44	27.6±0.3
<i>Sporobolus iocladius</i> (Nees, ex Trin) Nees.	Poaceae	74.6±0.8	9.0±0.2	35.2±1.7	5.9± 0.6	6.0±0.4	-	77.6±0.8
<i>Panicum turgidum</i> Forsskal	Poaceae	68.0±0.2	18.3±0.3	35.5±0.3	15.0±0.8	14.0±0.5	33.87±0.61	66.0±0.5
<i>Panicum antidotale</i> Forsskal	Poaceae	92.7±0.7	20.7±0.3	-	6.0±0.6	22.8±0.5	-	256.3±1.4
<i>Lasiurus scindicus</i> Henrard.	Poaceae	54.3±0.5	43.7±0.5	-	10.1±1.2	54.7±0.5	-	45.0±1.5

Values for Arbuscular Mycorrhiza (AM) and Dark Septate Endophyte fungus (DSE) are mean±SEM (N = 10) and for AMF spore densities N = 5

experiment was initiated on the 3rd March, 2005 in the nursery of Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur. River sand and earth was mixed in the ratio of 1:2, autoclaved at 121°C for half an hour for three times with one hour interval to kill the indigenous micro flora and fauna. A layer of 100 g rhizosphere soil from each grass species (taken from the mixed soil as described earlier) was spread over the autoclaved mixture in the tubes. *Panicum antidotale* grass was used as bait because it has thick fibrous roots, showed highest incidence of AM colonization and relatively high number of spores in its rhizosphere soils. Healthy seeds of *Panicum antidotale* were surface sterilized with 0.01% (w/v) HgCl₂ for 2 min and washed for several times with distilled water following Chaurasia and

Khare (2005). Seeds were germinated in 22.5 cm petriplates on the wet filter papers up to two leaves stage and transplanted to the plastic tubes containing inoculums. Harvesting was commenced after 10 weeks and spores were extracted from the 50 g of soil by wet sieving and decanting method (Gerdemann and Nicolson, 1963).

For identification each spore type was mounted in water, lactophenol and Melzer's reagent (Morton, 1988) separately for identification. The identification was based upon spore colour, size, wall orientation and attachment of subtending hyphae as given on the web site <http://invam.caf.wva.edu> by International collection of vesicular and arbuscular mycorrhizal fungi (INVAM) and the original species descriptions of Trappe (1977), Nemea *et al.* (1981) and Morton (1988). The permanent

Table 3: Rhizosphere edaphic features of perennial grass species collected from Cholistan desert, Pakistan

Table 1: Descriptive Chemical Features of top mineral glass species collected from Chonistan district, Pakistan														
Sites	Soluble cations			Soluble anions			Total N (%)	Avail-able P (ppm)	Organic matter (%)	Water holding capacity (%)	Moisture (%)	pH (1:2 H ₂ O)	EC (μ S cm ⁻¹)	Textural classes
	(mEq 100 g) Ca ⁺⁺ and Mg ⁺⁺	Na ⁺	K ⁺	(mEq 100 g) CO ₃ ²⁻ and HCO ₃ ⁻	Cl ⁻									
S1	2.38	1.27	0.63	1.51	1.14	0.34	0.81	0.74	25	2.82	8.7	148	Sandy	
S2	3.54	1.52	0.92	2.93	2.60	0.70	2.67	1.45	40	3.33	9.0	139	Sandy	
S3	4.94	0.23	0.15	1.75	1.78	1.19	2.90	1.33	39	3.56	8.6	118	Sandy	
S4	5.00	0.30	0.05	3.08	2.31	0.24	1.90	0.59	35	2.66	8.2	112	Sandy loam	
S5	3.42	0.23	0.07	2.40	2.63	0.16	1.24	0.44	32	1.33	8.6	128	Sandy loam	
S6	3.22	0.29	0.26	3.25	2.16	0.18	1.60	0.49	34	2.86	8.1	207	Loamy sand	
S7	3.56	2.15	1.16	2.54	1.87	0.38	1.34	0.55	29	2.64	8.7	406	Sandy	

slides and specimens were deposited to the Biological Laboratory collection of fungi, Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur, Pakistan.

AMF propagules frequency estimation: The percent absolute and relative frequency was calculated as given by Cox (1967).

$$\% \text{ Absolute frequency} = \frac{\text{No. of rhizosphere soils in which an AM species occurred}}{\text{Total No. of rhizosphere soils examined}} \times 100$$

and

$$\% \text{ Relative frequency} = \frac{\text{No. of occurrences of No. AM species occurred}}{\text{No. of occurrences of all the AM specie}} \times 100$$

The total number of AM species was calculated by summing up all kinds of species in the rhizosphere soil of each grass species.

Soil analysis: For the physico-chemical analyses of rhizosphere soil, samples were given to the Analytical Laboratory of Department of Chemistry, The Islamia University of the Bahawalpur and parameters such as soluble cations and anions, total N and P contents, percentages of organic matter, water holding capacity and moisture, pH and EC rhizosphere soil samples were studied and the results were tabulated in Table 2.

Statistical analysis: The statistical analyses like Regression correlation between DSE and AM, Standard Errors, averages for percentages of AMF and spore densities were calculated by using SPSS software on Pentium-IV.

RESULTS

Site and soil characteristics: The site characteristics are given in Table 1. It is evident that the selected sites were

quite distant from each other and with diversified grass species floristic composition. The idea was to have maximum variability of mycorrhizal status and distribution in these grasses. The vegetation at all the study sites was patchy, less grazed and with minimum human intervention. Grasses like *Cypres conglomeratus*, *Cyperus rotundus* and *Panicum turgidium* were found to be widely distributed and were encountered both in the lesser and greater Cholistan while *Sporobolus iocladius* was found only at the two study sites (S6 and S7) that lied only in the greater Cholistan.

Table 3 represents the physicochemical features of rhizosphere soils. The texture of the soil varied from sandy to sandy loam to loamy sand. The soils at all the study sites were alkaline with high pH values with the maximum (9) at site S2 and minimum (8.1) at site S6. The EC values varied from 112 μS cm⁻¹ at site S7 to 406 μS cm⁻¹ at site S4. Among the soluble cations Calcium and Magnesium were relatively high at site S4 while contents of Sodium and Potassium were high in the rhizosphere soils collected from site S7. On the other hand from soluble anions, the contents of Carbonates and Bicarbonates and Chlorides were relatively high at site S6 and S5 respectively. The sites S2 and S3 seems to be in better position with high percentages of total Nitrogen, organic matter and water holding capacity along with available Phosphorus.

AMF infection of roots: Results in Table 2 showed that all the grasses studied had AMF colonization on their roots; however, it was quite variable from species to species. The maximum percentage of colonization (92.7%) was recorded in the roots of *Panicum antidotale* followed by *Cenchrus biflorus* (78.3%), *Panicum turgidium* (68%) and *Cymbopogon jwarancusa* (65%). The highest percentage of AMF coiling (35.5%) was observed in *Cenchrus ciliaris* while AMF coiling was not observed in the roots of *Panicum antidotale*, *Lasiurus scindicus* and *Cyperus* species. The vesicles were more frequently encountered in the roots of *Saccharum bengalense* as compared to the other grass species whilst arbuscules were relatively more frequent in the roots of *Panicum turgidium* (Table 2).

Table 4: Percent absolute frequency and percent relative frequency of AMF species occurrence in the rhizosphere soils of perennial grass species

AM species	C.C.	C.R.	C.J.	C.B.	C.Ci.	O.C.	S.B.	S.I.	P.T.	P.A.	L.S.	Absolute frequency (%)	Relative frequency (%)
<i>G. fasciculatum</i> (Thaxter) Gerd and Trappe	+	+	+	+	+	-	-	-	+	+	+	72.7	14.2
<i>G. boreale</i> (Thaxter) Trappe and Gerd	-	-	+	-	-	+	-	-	+	-	+	36.3	7.2
<i>G. Mossae</i> (T. H. Nicolson and Gerd) Gerd. and Trappe	-	+	+	+	+	-	-	-	-	-	-	36.3	7.2
<i>G. deserticola</i> Trappe, Bloss and Menge	-	-	+	+	+	-	-	+	+	+	-	54.5	10.7
<i>G. pulvinatum</i> (Henn.) Trappe and Gerdemann	+	-	+	-	-	-	+	-	-	-	+	27.2	7.2
<i>G. constrictum</i> Trappe	-	-	+	+	+	-	-	-	-	+	-	36.3	7.2
<i>G. albidum</i> Walker and Rhodes	-	+	-	-	-	-	+	-	-	-	+	18.1	5.3
<i>G. caledonium</i> (Nicol. and Gerd.) Trappe and Gerd	-	-	-	-	+	-	-	-	-	+	+	36.3	5.3
<i>G. aggregatum</i> Schenck and Smith	+	+	+	-	-	+	-	+	-	+	-	54.5	10.7
<i>Gl. Rosea</i> Mukerji, Tewari and Skoropad	+	-	+	+	+	-	-	-	-	-	+	45.4	8.9
<i>Gl. margarita</i> Becker and Hall	-	-	+	-	+	-	-	-	+	+	-	36.3	7.2
<i>Sclerocystis pakistanica</i> Iqbal and Bushra	-	+	+	-	-	-	+	-	+	+	-	45.4	8.9
Total number of AMF species	4	5	10	5	7	2	3	2	5	7	6		

CC = *Cyperus conglomeratus*, CR = *Cyperus rotundus*, CJ = *Cymbopogon jwarancusa* CB = *Cenchrus biflorus*, CC = *Cenchrus ciliaris*, OC = *Ochthochloa compressa*, SB = *Saccharum bengalense*, SI = *Sporobolus iocladius*, PT = *Panicum turgidum*, PA = *Panicum antidotale*, LS = *Ladiurus scindicus*

$$\text{Percent Absolute Frequency} = \frac{\text{No. of rhizosphere soils in which an AM species occurred}}{\text{Total No. of rhizosphere soils examined}} \times 100$$

and

$$\text{Percent relative frequency} = \frac{\text{No. of occurrences of one AM species}}{\text{No. of occurrences of all the AM species}} \times 100$$

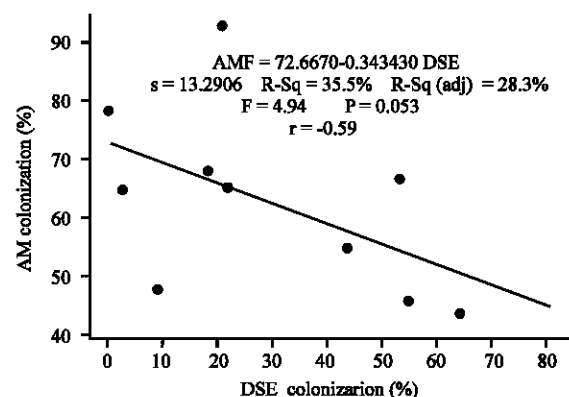


Fig. 1: Regression between percent AMF colonized root length and DSE in eleven perennial grasses collected from cholistan desert

Present study depicts that except *Cenchrus biflorus*, the (Dark Septate Endophyte) DSE fungi were the constant feature along with AMF colonization in rest of the grasses. We found that both AM and DSE have negative effect upon each other when tested with liner regression ($R^2 = 35.5\%$, $R^2(\text{adj}) = 28.3\%$, $F = 4.94$, $p = 0.053$, $n = 11$) (Fig. 1).

AMF spores extracted: It is evident from Table 2 that the average spore numbers were highly variable. The maximum average number of AM spores (per 100 g soil) was extracted from the rhizosphere of *Cenchrus biflorus* followed by *Panicum antidotale* and *Cyperus rotundus*. The lowest number of AM spores was extracted from the rhizosphere of *Ochthochloa compressa*.

AMF species frequency estimation: Percent absolute frequency and percent relative frequencies of AMF species are given in Table 4. It shows that *Glomus fasciculatum* was the most frequently occurred species with 14.2 relative frequency of occurrence while *Glomus deserticola* and *Glomus agrigatum* had comparatively less frequency of occurrence. The maximum number of AMF species was encountered in the rhizosphere of *Cymbopogon jwarancusa* and least in the rhizospheres of *Ochthochloa compressa* and *Sporobolus iocladius*.

DISCUSSION

Eleven perennial grass species were collected from diverse rangeland habitats of Cholistan desert. Grasses like *Cyperus conglomeratus*, *Cyperus rotundus* and *Panicum turgidum* were found to be widely distributed and were encountered both in the lesser and greater Cholistan while *Sporobolus iocladius* was found only at the two study sites (S6 and S7) that lied only in the greater Cholistan. We were unable to find this grass at the study sites selected in the lesser Cholistan. *Sporobolus iocladius* is a perennial salt secreting grass and has good fodder value (Gulzar *et al.*, 2005). It's distribution extends from marshes of the Arabian sea coast to the salt flats and saline deserts in northern Pakistan (Cope, 1982) but as concern to the Cholistan desert it seemed to be only confined to the saline patches (i.e., Sites 6 and 7, Table 3). We have already reported the presence of *Sporobolus iocladius* near Fort Moujgarh where it was found growing around some salt patches (Chaudhry *et al.*, 2005). The wide spread grass species seemed to have wider ecological amplitude and may

prove very useful for the restoration of degraded desert lands (Mohammad *et al.*, 2000). While many wide spread species demonstrate adaptive genetic variation over their range, others maintain wide ecological amplitude, apparently by means of one or more adaptable phenotypic characteristics (Bradshaw, 1965; Lesica and Allendorf, 1999).

In this study we found that the AMF colonization was highly variable. Number of authors have reported that different species may have varied levels of AMF (Koske *et al.*, 1997; Wilson and Hartnett, 1998; Bohrer *et al.*, 2001) however a single species may also be different in colonization levels when collected from different sites in the same season which depicts that soil chemical composition and inoculum potential can also strongly effect the AMF colonization (Brown and Morton, 1996; Miller, 2000). The root samples for the present study were collected at the end of rainy season and at the start of winter in Cholistan desert. At that time all the perennial grass species were at the beginning of flowering or at full bloom. It has been demonstrated that AM colonization within plant communities and populations depends upon the factors like stage of the plant development, availability of inoculums, season and susceptibility to inoculum and nutritional status of the plant (Friesse and Allen, 1991; Sanders and Fitter, 1992). In the present study both the *Cyperus* species were found to be mycorrhizal. These finding are quite in line with the findings of Muthukumar and Udaiyan (2000), Harikumar (2001), Silva *et al.* (2001). Hundred percent studied grasses were found with vesicles in their roots however only 27.2% grass species showed arbuscules.

Intraradical structures such as vesicles are frequently reported in AM colonized roots; however, the reports on the occurrence of arbuscules in sedges are limited (Muthukumar *et al.*, 2004). In addition continuous persistence of AMF colonized perennial grass roots may serve as prapagules and may play an important role in either regeneration of dormant perennial plants or in the development of new seedlings.

Soil fertility and pH are reported to affect the efficiency of mycorrhiza host interaction for the acquisition of nutrients. The soil ph determines the solubility of many nutrients such as Fe, Mn, Zn, P and Mo and therefore, directly determines that how much host plant can take benefit out of mycorrhizal colonization (Muthukumar *et al.*, 2004). The probability of mycorrhizal colonization increases with the increase of soil pH because the availability of nutrients decreased with increasing pH (Brady, 1990). Our study shows that all the rhizosphere soils collected from all the study sites have high pH values (Table 3). This may be the one reason that all the grass species have incidence of mycorrhiza (Table 2).

On the basis of present study we found that DSE fungi are negatively correlated with the AMF. The roots of grasses and sedges are commonly found to be colonized under the condition where the mycorrhizal fungi do not proliferate easily (Treu *et al.*, 1995) however, contrasting results has been reported by Ruotsalainen *et al.* (2002) when they studied the effect of seasonality on the correlation between AMF and DSE in low-alpine herbs. The functional relationship between DSE and host may be analogous to that of AM fungi and their host. Haselwandter and Read. (1982) suggested that colonization with DSE seemed to be mutualistic rather than parasite because in examining the role of DSE in the ecology of *Carex* species of high alpine, DSE inoculation enhanced the biomass and P- relation of *Carex* species (Haselwander and Read, 1982) but DSE colonization did not show the usual mycorrhizal structures such like arbuscules and coils as in ericoid mycorrhiza. Consequently, it would be too early to say with surety that DSE fungi may act as substitute for AMF in enhancing the plant growth and fitness in the natural ecosystems.

It is evident from Table 2 that the average spore numbers are highly variable and less in the rhizosphere soils. The present findings are quite in line with the reports of Pond *et al.* (1984) and Stutz and Morton (1996). They found less number of AMF spores in the arid soils but are in contrast with the findings of Tao *et al.* (2004) where they found high average number of AMF spores in an arid valley type savanna in Southwest China. The samples for the present study were collected during October and November when there was end of summer and climate was mild in Cholistan desert. The plants specially the perennial grasses were at their full vigor. This situation may have effect the spore densities as it had been suggested that AMF spore abundance and colonization are governed by the growth stages of plants (Kennedy *et al.*, 2002) and soil moisture as high edaphic moisture may enhance the spore production (Jackobson, 1997).

The results of the present study hold our previous report (Chaudhry *et al.*, 2005) that the *Glomus* is the dominant genus in Cholistan desert (Table 4). *Cymbopogon jwarancusa* is an aromatic grass and can grow on variety of soils this may be one reason that highest number of AMF species was found in the rhizosphere of this plant because soil properties may effect the distribution of spores such as organic mater had been positively related to spore production and density in some ecosystems (Klironomos *et al.*, 1993). Spore abundance had also been shown to be related with variations in moisture (Anderson *et al.*, 1986), pH (Porter *et al.*, 1987) and temperature (Koske, 1987).

However, such relationships did not always remain the same. For example, Friese and Koske (1991) did not find any correlation between AMF spore densities in a small spatial study. Another possible explanation for the *Glomus* species dominance may be the availability of moisture and time taken for maturity i.e., *Glomus* species spores being smaller in size may have less time to reach maturity as compared to Gigasporaceae during the short periods of moisture regimes in the arid areas like Cholistan desert (Boddington and Dodd 2000; Tao *et al.*, 2004).

In short, heavy incidence of mycorrhiza in all the perennial grasses suggests that they are mycorrhizal dependent. However, the level of their dependency may be variable according to plant phenology (Wilson and Hartnett, 1998). The negative correlation between the DSE and AMF supports the hypothesis that DSE may form the symbiotic associations with the roots of their host plants (Jumpponen, 2001) but there is no direct evidence that DSE enhance the nutrient acquisition. Very low number of AM species in the rhizosphere of *Sporobolus iocladius* and *Ochthochloa compressa* may be attributed to the host preference (Plenchette *et al.*, 1983) but edaphic factors can play a vital role in the AMF species composition (Bohrer *et al.*, 2001; David and Wilson, 2002). More in depth studies are required to ascertain the defined role of mycorrhiza and DSE for the development of perennial grasses of Cholistan desert either at individual or community level.

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