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Short communication

Arbuscular Mycorrhizae in association with aquatic and marshy plant species in Goa, India

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Abstract

Of the 20 plant species of hydrophytes screened for Arbuscular Mycorrhizal (AM) fungal root colonization, 10 aquatic plants (out of 14 species) and five marshy plants (out of six species) were found to be mycorrhizal, while the remaining species were non mycorrhizal. Vesicular colonization occurred in 12 plant species while arbuscular colonization was restricted to only three plant species. A rooted submerged pteridophyte viz., *Isoetes coromandelina* L. was found to be mycorrhizal exhibiting vesicular colonization. In all, two genera viz., *Glomus* and *Scutellospora*, the former being dominant, were recorded. The most common AM fungal species *Glomus claroideum* was recovered from 14 plant species.

Keywords: Aquatic; Marshy; Hydrophytes; Plant species; AM fungi; Colonization

1. Introduction

Plant root-fungal interactions, called mycorrhizae, are found in approximately 90% of all vascular plants (Allen, 1991). Arbuscular mycorrhizae clearly play important roles in terrestrial ecosystems, such as grasslands, where they influence plant community structure and nutrient cycling (Jackson and Mason, 1984). Since AM fungi require oxygen to thrive and since many wetland plants have been described as non-mycorrhizal (Mosse et al., 1981; Anderson et al., 1984; Mejstrik, 1984), it has been assumed that AM fungi have little significance in wetland ecosystems. However, recent field studies show that AM fungi exist in wetlands and colonize many hydrophytic plants (Brown and Bledsoe, 1996; Cooke and Lefor, 1998; Turner and Friese, 1998; Cantelmo and Ehrenfeld, 1999; Thormann et al., 1999; Turner et al., 2000). Arbuscular mycorrhizal (AM) fungi have been found in roots of submerged macrophytes (Clayton and Bagyaraj, 1984; Tanner and Clayton, 1985), salt marsh plants (Rozema et al., 1986; Van Duin et al., 1990), plants in oligotropic wetlands (Sondegaard and Laegaard, 1977), wetland woody species (Keeley, 1980; Lodge, 1989), plants in prairie potholes (Wetzel and van der Valk, 1996) wetland plants in Everglades (Azi et al., 1995) and plants in recently rehabilitated wetlands (Turner and Friese, 1998). Nine of 49 species examined in aquatic habitats of Denmark were found to be mycorrhizal (Beck-Nielsen and Vindaek, 2001).

The association between AM fungi and aquatic plants may mediate co-existence of aquatic plant species and keep balance of the hydrophytes community as in terrestrial ecosystems (Hart et al., 2003). The primary abiotic factors known to influence the abundance and distribution of AM fungi in aquatic ecosystems are water, nutrient and oxygen availability (Read, 1991). One of the main functions and ecological roles of AM fungi is providing enhanced phosphorus nutrition to plants; thus the effect of soil available phosphorus is often assessed in wetland ecosystems (Smith and Read, 1997). The AM fungal colonization of wetland plants may be particularly dependent on the interaction between plant phenology and soil wetness (Miller, 2000). One of the recently accepted theories of arbuscular mycorrhizae suggest that these fungi were influential in colonizing land by aquatic plants, based on fossil evidence from Rhynie chert (Smith and Read, 1997). This paper presents a study of the AM fungal diversity in plants growing in aquatic and marshy habitats of Goa.

2. Materials and methods

Fourteen aquatic plant species and six marshy plant species were collected from three localities viz., Santa Cruz, Taleigao

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and Vasco of Goa State during the period July 2004–September 2004. Roots were gently washed and fixed in FAA (Formalin–Acetic acid–Alcohol) and transported to the laboratory for processing. Fixed roots were washed free of FAA, and cut into 1 cm root bits, cleared in 10% (w/v) KOH at 90 °C for 30–45 min, thoroughly rinsed in water, acidified with 5 N HCl and stained in acetic glycerol containing 0.5% (w/v) trypan blue and observed under light microscope for the presence or absence of AM colonization (Phillip and Hayman, 1970).

Trap cultures were established by using roots and rhizosphere soils except for free floating plants where only roots were used. The soil samples were mixed with autoclaved sand in a ratio of 1:2 (v/v) and filled in 15-cm diameter pots. Pots were planted with cuttings of *Coleus* sp. and watered regularly. After three months, the plants were cut at the soil surface and replanted with the same host. The plants were allowed to grow for an additional three months, at which time they were sampled for determination of AM fungal species. The spores isolated from the trap cultures using the wet sieving and decanting procedure (Gerdemann and Nicolson, 1963) were used to identify the AM fungal species. Intact and crushed spores in PVLG (Poly vinyl alcohol–lactic acid–glycerol) solution (Koske and Tessier, 1983) with or without Melzers reagent were examined under Leica compound microscope and identified based on spore morphology and sub-cellular characters and compared with original descriptions (Schenck and Perez, 1990; Almeida and Schenck, 1990; Redecker et al., 2000; Morton and Redecker, 2001; Schüßler et al., 2001). Spore morphology was also compared with the culture data established by International Collection of Vesicular Arbuscular Mycorrhizal Fungi (http://invam.cag.wvu.edu). Voucher specimens of AM fungi have been retained in the Botany Department, Goa University, Goa, India.

3. Results

In the present study, a total of 20 species of aquatic and marshy plants were surveyed for AM fungal root colonization. Out of the total 20 plant species, root colonization of AM fungi was recorded in 16 species. Vesicular colonization was the most prevalent type and was recorded in 12 species (Table 1). In rooted plants with floating leaves, *Marsilea quadrifolia* showed the presence of vesicular colonization whereas no AM fungal root colonization was observed in *Nymphaea stellata*. The free-floating plant species viz., *Pistia stratiotes* and *Salvinia natans* exhibited vesicular colonization. The two submerged floating plants viz., *Najas minor* and *Ceraptoteris thalictriodes* did not show any AM fungal root colonization. Rooted submerged plants viz., *Blyxa echinosperma*, *Isoetes coromandelina* (a peridophyte), *Eriacaulon cinereum*, *Rotala malampuzhensis* and *Rotala densiflora* recorded the presence of AM fungal colonization, whereas *Scripus lateriflorus* (Cyperaceae) recorded the absence of fungal root colonization. The rooted emergent plants viz., *Lymnophila indica* and *Monocoria vaginalis* showed vesicular colonization in the roots. Out of

Table 1
Arbuscular Mycorrhizal fungal colonization and AM fungal species identified in aquatic and marshy plants

Sr. no.	Hydrophytes	Family	Locality	AM fungal colonization	AM fungi identified
I. Rooted submerged plants					
1	*Blyxa echinosperma* (Clarke) Hook.f.	Hydrocharitaceae	Taleigao	H V	*Glomus claroideum, Scutellospora* sp.
2	*Eriacaulon cinereum* R. Br.	Eriocaulaceae	Taleigao	H V	*Glomus claroideum*
3	*Isoetes coromandelina* L.	Isoetaceae	Taleigao	H V	*Glomus claroideum*
4	*Rotala malampuzhensis* Nair ex cooke.	Lythraceae	Taleigao	H A	*Glomus claroideum*
5	*Rotala densiflora* (Roth) Koehne	Lythraceae	Taleigao	H A	*Glomus claroideum*
6	*Scripus lateriflorus* Gmel.	Cyperaceae	Taleigao	–	–
II. Rooted emergent plants					
7	*Lymnophila indica* (L.) Druce	*Scrophulariaceae*	Santacruz	H V	*Glomus claroideum*
8	*Monocoria vaginalis* (Burm. f.) Persl ex Kunth	*Pontederiaceae*	Taleigao	H V	*Glomus claroideum*
III. Rooted plants with floating leaves					
9	*Marsilea quadrifolia* L.	Marsilaceae	Santacruz	H V	*Glomus* sp.
10	*Nymphaea stellata* Willd.	Nymphaceae	Taleigao	–	–
IV. Submerged floating plant					
11	*Najas minor* (Pers.) All Fl.	Najadaceae	Santacruz	–	–
12	*Ceraptoteris thalictriodes* L	Ceratophyllaceae	Taleigao	–	–
V. Free-floating plants					
13	*Pistia stratiotes* L.	*Araceae*	Vasco	H V	*Glomus claroideum, Scutellospora verrucosa*
14	*Salvinia natans* Allioni.	Lamiaceae	Santacruz	H V	*Glomus claroideum*
VI. Marshy plants					
5	*Drosera indica* L.	Droseraceae	Taleigao	H V	*Glomus claroideum*
16	*Lindernia ciliata* Cols (Penn).	Veronicaceae	Taleigao	H V	*Glomus claroideum*
17	*Ludwigia parviflora* Roxb.	Onagraceae	Taleigao	H V	*Glomus claroideum*
18	*Murdannia semeteres* Dalz.	Commelinaceae	Taleigao	H V	*Glomus claroideum*
19	*Utricularia reticulata* Smith.	Lentibulariaceae	Taleigao	–	–
20	*Centella asiatica* (L.) Urb.	Apiaceae	Santacruz	H A	*Glomus claroideum*

H: Hyphal; A: Arbuscular and V: vesicular, (–): absent.

a total six marshy plant species, five species viz., *Drosera indica*, *Ludwigia parviflora*, *Murdania semeteris*, *Centella asiatica* and *Lindernia ciliata* showed the presence of AM fungal colonization. Except for *C. asiatica*, the remaining four marshy species exhibited vesicular colonization.

Four species of AM fungi belonging to two genera viz., *Glomus* and *Scutellospora* were recovered in the pot cultures prepared from 10 hydrophytes and five marshy plant species (Table 1). *Glomus* was the dominant genus and was recovered from pot cultures prepared from all the 15 plant species. The genus *Scutellospora* was recovered from two hydrophytes viz., *B. echinosperma* and *P. stratiotes*. *Glomus claroideum* was the most dominant species colonizing a total of 14 plant species.

4. Discussion

The present study confirms the AM association in hydrophytes. Colonization of AM fungi was indicated by the presence of darkly stained vesicles and arbuscules in the roots. In this study, 71.43% of aquatic plants and 83.33% of marshy plants were found to be arbuscular mycorrhized. The present study confirms the earlier reports that arbuscles are rare in hydrophytes (Cantelmo and Ehrenfeld, 1999). The study also confirms the earlier findings of Bagyaraj et al. (1979) who reported the absence of mycorrhizal root colonization in *Nymphaea stellata*. However, Firdaus-e-Bareen (1990) reported AM fungal root colonization in *N. stellata* and also in free floating plant *P. stratiotes*. Free floating plant species viz., *P. stratiotes* and *S. natans* and rooted emergent species viz., *Lymnophilia indica* and *M. vaginalis* accounted for 100% AM fungal colonization. An explanation for the increased colonization of emergent and free floating plants might be that in the present study these four species were collected from shallow water where there was a relatively high redox potential in the sediments compared the deeper part of water and a potentially greater photosynthetic efficiency of the host. Higher photosynthetic efficiency of the host and redox potential were considered respectively to facilitate the colonization of AM fungi indirectly and directly (Khan, 1993; Wigand et al., 1998). Arbuscular mycorrhizal colonization in *M. quadrifolia* was also reported by Iqbal et al. (1988) and Firdaus-e-Bareen (1990). The observations recorded in the present study are contradictory to the findings of Dharmarajan et al. (1993) who reported the absence of AM fungal colonization in *L. parviflora*. Many common wetland plant families, most notably the Cyperaceae had been previously categorized as non-mycorrhizal because in few species roots were observed to harbor the fungus (Powell, 1975; Newman and Reddell, 1987; Brundrett, 1991; Peat and Fitter, 1993; Smith and Read, 1997), but there have been numerous reports of mycorrhizal colonization in certain Cyperaceae species (Koske et al., 1992; Wetzel and van der Valk, 1996; Lovera and Cuenca, 1996). Variation in the mycorrhizal condition in Cyperaceae may be due to environmental and edaphic factors rather than a phylogenetic constraint per se (Read, 1984), because AM colonization seems to be negatively correlated with soil moisture (Anderson et al., 1984). It has been speculated that non-mycorrhizal state of some Cyperaceae members might result from their presence in marshy, anaerobic soils rather than their taxonomic position (Tester et al., 1987).

A relatively few species of AM fungi were found to be associated with the plant species selected for the study. Glomus species were predominant among two genera viz., *Glomus* and *Scutellospora* identified from rhizosphere soil, of which *Glomus clariodeum* was the most dominant accounting for 70% of total AM fungal species. This could be due to the fact that the number and type of AM fungal spores will depend on both the fungal species (Tommerup and Abbott, 1981) and the extent of root colonization (Douds and Schenck, 1990).

This study also confirms the fact that AM fungi are an important part of aquatic community but they are less frequently than the terrestrial plants. This may be attributed to the poorly developed root system and also due to the fact that nutrients can directly be absorbed from water by root as well as shoot system of the plant. Although the roles of AM fungi are still not fully understood in aquatic and marshy environments, the results from this study imply that AM associations are functional in, and are a significant component of aquatic plant communities mainly for plant competition, succession and diversity in fens and marshes (Newman and Reddell, 1988; van der Heijden et al., 1998; Carvalho et al., 2001; Facelli and Facelli, 2002). Because of these ecological implications, AM associations and the seasonal dynamics of AM colonization should be considered in plans for the ecological restoration of functional wetlands and should be a significant component of studies assessing aquatic ecosystem dynamics.

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