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SHORT NOTE

Arbuscular mycorrhizal status of some Kashmir Himalayan alien invasive plants

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Abstract In view of the recently reported role of arbuscular mycorrhizas (AM) in plant invasions, we examined 63 alien plant species representing 26 families, collected from diverse habitat types in the Kashmir Himalaya, India, for the extent and type of their AM association. Based on the percent AM fungal root length colonization (% RLC), the investigated plants were categorized into five classes (class A = 0–5% RLC, class B = 6–25%, class C = 26–50%, class D = 51–75%, and class E = 76–100%). The number of species belonging to each of these classes was 7, 6, 22, 19, and 9, respectively. The AM colonization in 33 plant species was of *Arum*-type, 18 species was of *Paris*-type, and eight species harbored an intermediate type. Such baseline information on a large number of alien plants inhabiting diverse habitats in different biogeographical regions is needed for elucidating the role of AM fungi in alien plant invasions.

Keywords Mycorrhizal status · *Arum*-type · *Paris*-type · Plant invasion · Kashmir Himalaya

Introduction

The enormous ecological and socio-economic damage inflicted by plant invasions (Pimentel et al. 2005) has stimulated great interest in the possible contribution of above- and below-ground mutualistic and antagonistic organisms in the success or failure of alien plants invading non-native ecosystems. Like most native plants, the growth and fitness of many alien plant species depend upon mutualistic associations with soil microbes, such as arbuscular mycorrhizal fungi (AM) (Smith and Read 1997; Richardson et al. 2000). Some alien plants, unlike native plants, have been reported to drive mycorrhizal associations to their own benefit in the invaded ecosystem (Shah and Reshi 2007) through the avoidance of herbivores (Abigail et al. 2005) and alteration of competitive interactions with native plant species (Shah et al. 2008). While certain studies have shown that naturalized exotic plants are less responsive to native AM fungi than native plants (Vogelsang et al. 2004), our recent studies (Shah et al. 2008) have shown exactly the opposite. Some non-mycorrhizal species of invasive plants have been reported to proliferate in ecosystems with high AM fungal density (Mooney and Hobbs 2000; Stinson et al. 2006). However, proliferation of plants with low mycorrhizal dependency may diminish AM fungal density in soils (Vogelsang et al. 2004), which in turn may be detrimental to native plant productivity and diversity (van der Heijden et al. 1998).

As regards morphological AM types (Gallaud 1905; Dickson et al. 2007), *Arum*-type is more common in weedy plants (Yamoto 2004) and decrease in the ratio of *Arum* to *Paris* type AM colonization from pioneer to late successional stages (Ahulu et al. 2005) is indicative of some functional differences between them. Of late, not only some invasive plants have been reported to harbor the *Arum*-type AM (Fumanal et al. 2006, Shah et al. 2008), but this morphological type has also been linked to the rate of spread of some weedy plant species (Yamoto 2004).

Notwithstanding the multifaceted role of AM fungi in plant community structure and dynamics, no major survey

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exploring the mycorrhizal status of alien invasive plants has yet been carried out. It is in this context that the present study was conducted to evaluate the extent and type of AM occurrence in alien plant species at different stages of invasion in the Kashmir Himalaya, India.

Materials and methods

Study area and field survey

Field surveys were conducted in the Kashmir Valley (32° 20′ to 34° 50′ N and 73° 55′ to 75° 35′ E) during 2005–2008 to collect specimens of some alien plant species from different habitats, such as roadsides, abandoned agricultural fields, pastures and rangelands, etc., and these plants were examined for the extent and type of mycorrhizal colonization. The region has an area of about 15,948 km^2 within a large altitudinal range of 1,600 to 5,420 m above sea level (Fig. 1). Of the 63 species investigated during the present study, 39 species were widespread, as well as abundant in the region (invasive), 17 species were naturalized (species that are established with self-sustaining populations), six species were casual aliens (occasional with no self-replacing populations), and one species was a casual naturalized alien (adventive).

Mycorrhizal studies

Roots were collected from a minimum of ten plants per species and fixed in standard formalin–acetic acid alcohol solution. Samples were cleared and stained for assessment of mycorrhizal colonization using the technique of Phillips and Hayman (1970), and percent AM colonization was quantitatively estimated following McGonigle et al. (1990). Positive mycorrhizal status was assigned to all those species in which arbuscules were observed, though in most of them, vesicles and hyphae were also clearly distinct. The surveyed plants were categorized on the basis of percent AM fungal root length colonization into five subjective classes (class A, 0–5%; class B, 6–25%; class C, 26–50%; class D, 51–75%; and class E, 76–100%). Whether fungal hyphae were present mainly between cells (intercellular) or within cells as coils formed the basis of their classification

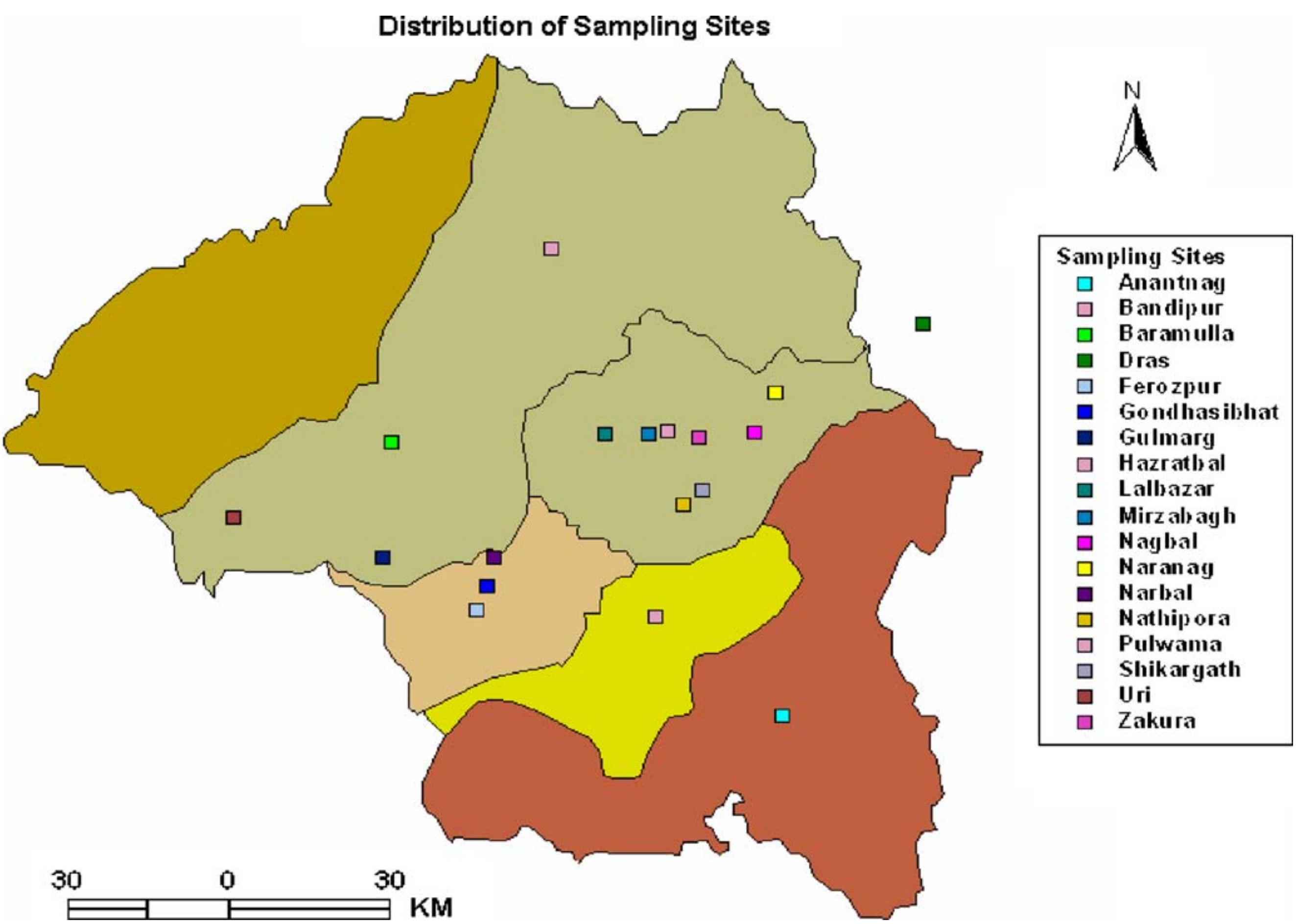

Fig. 1 Map of the Kashmir Himalayan region showing distribution of the sites surveyed for collection of the alien plants for assessment of their mycorrhizal status

Table 1 Origin, invasion status, percent root length colonization by AMF and morphological type of colonization of some Kashmir Himalayan alien plants

Family/plant species	Origin	Invasion status	%RLC by AMF	Type of colonization
Amaryllidaceae				
Allium cepa L.	Asia	Cs	27.5	*Arum*
Allium sativum L.	Europe	Cs	84	*Arum*
Apiaceae				
Daucus carota L.	Africa; Europe	In	76	*Paris*
Scandix pecten-veneris L.	Europe	Nt	66	*Paris*
Asteraceae				
Anthemis cotula L.	Europe	In	88	*Arum*
Artemisia absinthium L.	Europe	In	44	*Arum*
Centaurea iberica Trev. Ex. Spreng.	Asia; Europe	In	62	*Arum*
*Chrysanthemum cineriifolium*Vis.	Europe	Nt	86	*Arum*
Conyza canadensis Cronquist	North America	In	70	*Arum*
Carduus edelbergii Rech.f.	Europe	In	70	*Arum*
Crepis sancta Babc.	Asia	In	78	*Arum*
Galinsoga parviflora Cav.	South America	In	68	*Arum*
Lactuca dissecta D. Don	Europe	Nt	31	*Arum*
Senecio vulgaris L.	Europe	Nt	54	*Arum*
Sonchus arvensis L.	Asia; Europe	In	65	*Arum*
Xanthium spinosum L.	South America	In	62	*Arum*
Xanthium strumarium L.	Africa	In	25	*Arum*
Balsaminaceae				
Impatiens balsamina L.	Asia	Cs	31	*Arum*
Brassicaceae				
Brassica compestris L.	Europe	Cs	24.4	Intermediate
Capsella bursa-pastoris Medic.	Europe	In	0	
Nasturtium officinale R. Br.	Europe	Nt	0	
Sisymbrium loeselii L.	Africa; Europe	In	13	Intermediate
Caprifoliaceae				
Sambucus wightiana Wall. ex Wight & Arn.	Asia; Africa	In	43	Intermediate
Caryophyllaceae				
Cerastium glomeratum Thuill.	Europe	Nt	43.7	*Arum*
Stellaria media Cyr.	Europe	In	34.8	*Arum*
Chenopodiaceae				
Chenopodium album L.	Europe	In	0	
Chenopodium foliosum Aschers.	Asia; Europe	In	0	
Chenopodium hybridum L.	Asia; Europe	In	0	
Euphorbiaceae				
Euphorbia helioscopia L.	Asia; Europe	In	37.9	*Arum*
Fabaceae				
Medicago polymorpha L.	Africa; Europe	In	62	*Arum*
Trifolium pratense L.	Europe	In	78	*Arum*
Trifolium repens L.	Europe	In	72	*Arum*
Vicia faba L.	Asia; Africa	Nt	84	*Arum*
Geraniaceae				
Geranium rotundifolium L.	Asia; Europe	Nt	66.6	Intermediate
Hypericaceae				
Hypericum perforatum L.	Europe	Nt	31	*Paris*

Table 1 (continued)

Family/plant species	Origin	Invasion status	%RLC by AMF	Type of colonization
Iridaceae				
*Iris ensata*Thunb.	Asia	In	46	*Paris*
Lamiaceae				
Clinopodium umbrosum C. Koch	Asia; Europe	Nt	54	*Arum*
Marrubium vulgare L.	Asia; Europe	In	46	*Arum*
Salvia coccinea Eclinger	North America	Cs	45	*Arum*
Liliaceae				
Asparagus officinalis L.	Asia; Europe	Nt	49	*Arum*
Marsilaceae				
Marsilia quadrifolia L.	Europe	In	43	*Paris*
Onagraceae				
Oenothera rosea Ait.	South America	In	70	*Paris*
Oenothera glazioviana Micheli	North America	Nt	43	*Paris*
Oxalidaceae				
Oxalis carnaculata L.	Asia; Europe	Nt	44	*Paris*
Plantiginaceae				
Plantago lanceolata L.	Africa; Europe	In	80	*Arum*
Plantago major L.	Europe	In	72	*Arum*
Poaceae				
Aegilops tauschii Cosson	Africa	In	5	Intermediate
Avena fatua L.	Europe	Nt	24.6	*Paris*
Bothriochloa ischaemum Keng	Africa	In	32.5	*Paris*
Bromus inermis Leyss.	Europe	In	78	*Paris*
Digitaria longiflora Pers.	Africa	Nt	55	Intermediate
Hordeum vulgare L.	Europe; North America	Cs	65	*Paris*
Poa annua L.	Europe	In	55	*Paris*
Setaria viridis P. Beauv.	Asia; Africa	In	48	*Paris*
Sorghum helepense Pers.	Europe	In	25	*Paris*
Sorghum vulgare Pers.	Africa	Nt	48	*Paris*
Themeda anathera Hack.	Asia	In	54.5	*Paris*
Polygonaceae				
Polygonum hydropiper L.	Europe	In	58	*Paris*
Primulaceae				
Anagalis arvensis L.	Europe	In	50	Intermediate
Rosaceae				
Fragaria nubicola Lindel. Ex. Lacaita	Europe	Nt	5	*Arum*
Rubiaceae				
Gallium aparine L.	Africa; Europe	Cn	23	*Arum*
Scrophulariaceae				
Verbascum thapsus L.	Europe	In	43.3	*Arum*, intermediate
Urticaceae				
Urtica dioica L.	Africa; Europe	In	57	*Arum*

%RLC percent root length colonization, *In* invasive aliens (widespread and dominant naturalized plants), *Nt* naturalized aliens (established plants reproducing consistently with self-sustaining populations), *Cn* casual or naturalized aliens (naturalized species with occasional occurrence), *Cs* casual aliens (occasional species with no self-replacing populations)

into *Arum* or *Paris* type, respectively, following Smith and Smith (1997) and Dickson et al. (2007).

Results

Data (Table 1) revealed a high incidence of the AM symbiosis in plants at both species (92%) and family (96%) levels. However, the extent and type of AM colonization was variable (Table 1). Based on percent root length colonization, 7, 5, 22, 19, and 9 species were included in the classes A, B, C, D, and E, respectively. In percentage terms, the distribution of the investigated alien species into different frequency classes was 11% in class A, 10% in class B, 35% in class C, 30% in class D, and 14% in class E. While none of the members of the conventionally non-host family Chenopodiaceae harbored AM fungi, two members of another such family (Brassicaceae), namely, *Brassica compestris* and *Sisymbrium loeselii*, were found to be mycorrhizal. Thirty-three species harbored *Arum* type, 18 had *Paris* type, and eight species were with intermediate types of AM fungal colonization. The type of AM colonization in Brassicaceae members was arbuscular but morphologically different from both the *Paris* and *Arum* types, and was thus categorized as an intermediate type.

Discussion

Not only was a large number of species (92%) in the present survey mycorrhizal (Table 1), but the extent of their colonization was fairly high. In fact, about 78% of the species belonged to the classes C, D, and E, ranging from 25% to 100% mycorrhizal root length. Thus, the present observation is in contrast to that of Vogelsang et al. (2004), who observed that naturalized exotic plants are poorer hosts of native AM fungi than native plants. Since 80–90% of the land plant species and families are mycorrhizal (Wang and Qui 2006), the mere association of AM fungal symbionts with alien plants cannot be taken as an indication of their role in the promotion of alien plant invasions, although some recent studies (Fumanal et al. 2006; Shah and Reshi 2007; Shah et al. 2008) have shown promotion of invasiveness of some alien plant species by associated AM fungi.

The high incidence of *Arum*-type morphology in the investigated alien plants is in agreement with similar observations by Yamoto (2004), who suggested that this morphological type of AM colonization may be beneficial for fast-growing invasive plant species. Results of the present study also point towards the common occurrence of *Arum*-type AM in fast-growing invasive and weedy plant species.

The presence of a fine root system, as found in most of the investigated alien species, possibly facilitates higher AM fungal colonization (Zangaro et al. 2005) and, consequently, establishment, growth, and survival of host plants (Zangaro et al. 2003) in disturbed habitats. However, none of the members of Chenopodiaceae, a conventional non-host family, harbored AM fungi, but mycorrhizal association with two members of another non-host family (Brassicaceae), namely, *B. compestris* and *S. loeselii*, merits special attention. While the non-mycorrhizal nature of species in the Brassicaceae has perpetuated in the mycorrhizal checklist literature, this observation supports the suggestion of Dickie et al. (2007) that such checklists need to be used with caution. In conclusion, the present study highlights the need for detailed investigation of the mycorrhizal status of invasive plants in different biogeographical regions and habitat types for better understanding of the role of AM fungi in alien plant invasions.

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