Applied Soil Ecology 107 (2016) 182–190

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Soil and seasons affect arbuscular mycorrhizal fungi associated with *Tamarix* rhizosphere in arid and semi-arid steppes

Karima Bencherif[a,b], Ammar Boutekrabt[a], Yolande Dalpé[c], Anissa Lounès-Hadj Sahraoui[b,*]

[a] Université de Blida, Faculté des Sciences de la Nature et de la Vie, Route de Soumaa, BP 270, Blida 09000, Algeria
[b] Université du Littoral Côte d'Opale, Unité de Chimie Environnementale et Interactions sur le Vivant (UCEIV), EA4492, SFR Condorcet FR CNRS 3417, 50 rue Ferdinand Buisson, 62228 Calais, France
[c] Agriculture et agroalimentaire Canada, Centre de recherche et développement d'Ottawa 960 Carling Ave, Ottawa, ON KIA 0C6, Canada

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 24 May 2016
Accepted 9 June 2016
Available online xxx

Keywords:
Tamarix articulata
Tamarix gallica
AMF biodiversity
Mycorrhizal colonization
Pedological parameters

ABSTRACT

The arbuscular mycorrhizal fungi (AMF) diversity associated to *Tamarix articulata* and *Tamarix gallica* rhizosphere was investigated in the Algerian steppic area. Evaluation of species diversity revealed the presence of 10 glomoid and one gigasporoid spore types of AMF species from the ten studied sites. Shannon biodiversity index showed that AMF species diversity varied according to soil physico-chemical characteristics of the different sites. However, seasonal variation affected abundance but not AMF species biodiversity. Significant effect of soil and seasons on AMF root colonization rate was also observed. Overall, AMF *Tamarix* root colonization rates varied according to the species ranging from 0.88 to 75.26% in *T. articulata* and from 1.90 to 12.96% in *T. gallica*. This study highlighted the complexity of *Tamarix* species/AMF symbiosis through seasons associated with plant phenology and soil physico-chemical composition in arid and semi-arid steppes.

1. Introduction

Desertification is a major cause of land loss in pre-Saharian area. The steppe ecosystem consists of dry lands subjected to high evapotranspiration (Ollero, 2013; Dagar and Tomar, 2002). Steppic zones of Algeria were defined by Le Houerou et al. (1977) based on their bio-climates. They were characterized by their high soil salinity and calcareous level, conditions that hamper the ecosystem restoration (Ollero, 2013). Revegetation with selected plant species adapted to the harsh condition of steppic areas is an effective technique to fight against advancing desert and desertification (Dagar and Tomar, 2002).

Tamarix species that belong to the Tamaricaceae family are recognized to be well adapted to saline soil and arid environments (Meinhardt and Gehring, 2013). They can tolerate an extreme range of environmental conditions (Oudat and Quadir, 2011), and are resistant to high soil salinity levels such as those found in Algerian steppic ecosystems. This family includes 112 species from endemic regions of Eurasia and Africa and some species have been introduced into North America (Khabtane, 2010). *Tamarix gallica* L. and *Tamarix articulata* Vahll, two halophytic species, were introduced in some Algerian steppic areas during French colonial period. Since that time, they have spread naturally in several other arid and semi-arid areas (Belarouci, 1991; DGF, 2004).

T. gallica is a widespread species in coastal Mediterranean areas deciphering a high adaptability to different environments and a high tolerance to hard environmental conditions (Abou Jouadé et al., 2012). Its adaptability to saline soil made it efficient as a phytoremediator (Kadukova and Kalogerakis, 2007). *T. articulata* establishes in desert environments in North Africa and the Middle East, zones characterized by low rainfall, not exceeding 100 mm a year. The species is adapted to rich clay soil, with a moderate sand accumulation. This drought-resistant tree is tolerant to alkaline and saline soils and is commonly used as a windbreak and shade tree in oasis (Khabtane, 2010; UICN, 2014). *T. articulata* is one of most promising species for revegetation of bio-saline degraded soils and as such well suited to grow in steppic environments (Dagar and Tomar, 2002).

An interesting biological tool to improve plant growth and plant resistance in stressful environments is the establishment of mycorrhizal symbiosis (Fortin et al., 2008). Symbiotic fungi are important components of ecosystem diversity, due to the mutualistic interaction with roots of the terrestrial plants (Smith and Read, 2008). It has been clearly demonstrated that a diversity

* Corresponding author.
E-mail address: lounes@univ-littoral.fr (A. Lounès-Hadj Sahraoui).

http://dx.doi.org/10.1016/j.apsoil.2016.06.003
0929-1393/

of mycorrhizal fungi co-exists in natural communities and can have different effects on the plant growth, soil stability and stress resistance (Smith and Read, 2008; Wilson et al., 2009). The arbuscular mycorrhizal fungi (AMF) root colonization varies according to plant species, fungal and bacterial communities as well as soil environmental and plant physiological conditions (Smith and Read, 2008). Recent study showed that *T. articultata* is naturally associated with AMF (Bencherif et al., 2015). Beauchamp et al. (2005) found that AMF root colonization of the introduced *T. ramosissima* was very low. It seems that the mycorrhizal colonization status of *Tamarix* varies according to environmental conditions and species (Chaudhry et al., 2013).

In Algeria, tree plantation using *Tamarix* species is currently used for revegetation and soil stabilization (DGF, 2004). Before extending *Tamarix* species plantation through different areas of arid and semi-arid steppic zones, it is imperative to investigate on best cultivation practices including AMF. The present study aims to evaluate the AMF soil diversity associated with the rhizosphere of *T. articulata* and *T. gallica* grown under naturally colonized fields and in plantations of ten studied sites, located in arid and semi-arid ecosystems of Algerian steppes. Effects of seasons and soil parameters on AMF biodiversity and abundance as well as on *Tamarix species* colonization have been studied and discussed.

2. Material and methods

2.1. Site description and soil analysis

Ten sites of *Tamarix* populations in Algerian steppic area were selected, based on their respective soil texture and bioclimatic stage (Emberger, 1955) in order to investigate large spectra of *Tamarix* populations (Table 1). The studied sites were respectively: (1) Ain Oussera, (2) Boughzoul, (3) Djelfa, (4) Hassi Bahbah, (5) Kasr El Boukhari, (6) Laghouat, (7) Messaad, (8) El-Mesrane, (9) Salt Rocket (*Rocher de Sel*) and (10) Zaafrane. Weather conditions for the sampling year (2012/2013) corresponded to the characteristics of each region, except for a wet winter at site 1 and a wet spring at site 7 (Table 1). As indicated in Table 1, some sites were naturally colonized by *Tamarix* species and other were planted. Locations and distances between the different sites are indicated in Fig. 1.

Soil texture was estimated using textural triangle (USDA, 2013), Organic matter and organic carbon were determined by Walkley-Black method according to CEEAEQ (2003) using soil moisture and total calcareous content as described by Petard (1993). Soil samples were analyzed for pH on (1:5) soil: water suspension and soluble salt were determined by measuring the electrical conductivity (1:5) soil: water suspension at 25 °C (AFNOR,1995). Soil salinity was established according to USDA (2013) description. Available phosphorus (P) was measured according to Olsen method (1954). Total soil Nitrogen (N) was determined using the Kjeldahl method followed by titration of the distillates after Kjeldahl sample preparation and analysis (USDA, 2013). Available potassium (K), magnesium (Mg) and sodium (Na) were determined according to Nathan et al. (2012).

2.2. Soil and root sampling

Five mature *T. articulata* (Heights: 5–8 m) and five mature *T. gallica* (Heights: 2–4 m) at 20 m intervals were selected from each site. Samples were collected over area of 100 m^2 per site. A portion of the root systems and 1 kg of soil were collected from each plant at 25–50 cm depth at the middle of the four studied seasons and kept in labeled plastic bags at 4 °C until processing. Sampling dates for wet seasons were chosen right after heavy rain periods to favor and optimize AMF abundance. Summer sampling was done at the middle of the season in the most hot day. Soil sampling was done once every season. Soil and root samples were performed on ten *T. articulata* and nine *T. gallica* field sites. Five trees per site were selected for each *Tamarix* species and each site. Data were means of five replicates from each studied area.

2.3. Isolation and identification of AMF

AMF spores were extracted from 100 g of air-dried soil according to a wet sieving procedure described by Gerdemann and Nicolson (1963). *Tamarix* species rhizosphere soil samples were suspended in tap water, stirred and sieved sequentially through 250, 125 and 45 μm sieves under flowing tap water to separate the spores according to their sizes. Spores were deposited on a cavity microscopic slide and separated according to their

Table 1
Description of studied sites.

Studied sites	Official Name of sites	*Tamarix* species	*Tamarix* Status	M (°C)	m (°C)	R (mm/y)	Altitude (m)	Coordinates	Q_3	Bioclimatic stage (Emberger classification)
1	*Ain Oussera (Djelfa)*	*T.articulata*	Planted in 1980	34.00	0.81	217.65	694	35°25′07″N 2°54′20″ E	21.99	High arid with mild Winter
2	*Boughzoule (Medea)*	*T. articulata* & *T. gallica*	Native	34.5	0.86	172.5	635	35°42′03″N 2°50′17″ E	21.43	High arid with mild Winter
3	*Djelfa*	*T. articulata* & *T. gallica*	Planted in 1984	34.11	0.69	319.23	1131	34°40′00″N 3°15′00″ E	43.46	Average semi-arid with cold winter
4	*Hassi Bahbah (Djelfa)*	*T. articulata* & *T. gallica*	Planted in 1952	34.1	0.78	209.9	841	35°04′33″N 3°01′37″ E	25.79	Lower semi-arid with cold winter
5	*Kasr el Boukhari (Medea)*	*T. articulata* & *T. gallica*	Native	35.00	0.86	438	608	35°57′08″N 2°52′18″ E	20.62	Upper semi-arid with humid winters
6	*Laghouat (Laghouat)*	*T. articulata* & *T. gallica*	Native	39.6	2.10	320.12	750	32°55′08″N 2°30′32″ E	16.28	Lower Saharan with mild winter
7	*Messaad (Djelfa)*	*T. articulata* & *T. gallica*	Native	34.32	0.79	245.23	768	34°10′00″N 3°34′60″ E	25.05	Pre- Saharan with mild winter
8	*El-Mesrane (Djelfa)*	*T. articulata* & *T. gallica*	Planted in 1984	36.21	1.59	165.4	830	34°20′09″N 3°47′02″ E	25.63	Upper semi-arid with mild winter
9	*Salt Rocket (Djelfa)*	*T. articulata* & *T. gallica*	Native	35.5	1.2	279	1083	34°23′04″N 3°52′17″ E	27.9	Medium semi-arid with cold winter
10	*Zâafrane (Djelfa)*	*T. articulata* & *T. gallica*	Native	36.3	1.8	245.23	950	34°52′40″N 2°50′41″ E	24.37	Semi-arid lower with mild winter

M: maximum temperature; m: minimum temperature (M and m were observed in period of study); R: rain; (R: means of annual Rain way); Q_3: Emberger pluvio-thermic quotient.