Ecological Engineering 81 (2015) 93–101

Contents lists available at ScienceDirect

Ecological Engineering

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

Variation of soil nematode community composition with increasing sand-fixation year of *Caragana microphylla*: Bioindication for desertification restoration

Pingting Guan [a,b], Xiaoke Zhang [a,*], Jun Yu [a], Ningning Ma [a], Wenju Liang [a,*]

[a] State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110164, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Article history:
Received 7 November 2014
Received in revised form 5 February 2015
Accepted 5 April 2015
Available online 11 April 2015

Keywords:
Nematode communities
Vegetation restoration
Sand-fixation year
Sandy ecosystem
Bioindication

ABSTRACT

Vegetation restoration plays an important role in controlling desertification. The effects of vegetation restoration on aboveground biodiversity are well known. However, the effects of vegetation restoration on the belowground biotic communities in sand land are still highly important and need to be explored. We examined soil nematode community composition under *Caragana microphylla* of dominant native vegetation with 0- (the drifting sand dunes), 13-, 18- and 29-year sand-fixation and natural vegetation communities in Horqin Desert, China. The result showed that total nematodes, bacterivores, fungivores and omnivores-predators were all significantly affected by sand-fixation years, with their highest values being in 29-year sand-fixation. The conversion of drifting sand dunes to shrub land resulted in significant changes in *r*-strategists with *cp*-2 and *K*-strategists with *cp*-4 of soil nematodes. Nematode genera in different sand-fixation years were clearly separated by redundancy analysis and the preference of different nematode genera to habitat was discriminative. The effect of *C. microphylla* on soil abiotic properties and nematode communities was time-dependent. The significant variation of soil abiotic properties appeared from 18-year sand-fixation, and soil nematodes increased significantly after 13-year sand-fixation. The plantation of *C. microphylla* improved nematode diversity, with markedly higher values in the later sandy land stabilization stage than the drifting sand dunes. Furthermore, it can be concluded that soil nematode communities as bioindicators reflect the progressive restoration process of the sandy ecosystems.

1. Introduction

In sandy ecosystems, desertification may result in poor soil condition and low land productivity, which is a serious social and ecological problem (Lal, 2000). Ecosystem restoration measure is highly important for controlling desertification. For the reconstruction of ecosystem and its ecological function in sandy ecosystems, the vegetation restoration is one of the most effective ways to combat and control land desertification (Le Houérou, 2002; Ala et al., 2014; Liu et al., 2014).

In order to improve degraded sandy ecosystem, some native shrubs tolerant to nutrient-poor environment are planted on sandy lands. *Caragana microphylla* is an important shrub species for the restoration in the Horqin Desert, which is one of the most serious land desertification areas in China. *C. microphylla* could resist the shear force of wind erosion (Su and Zhao, 2003) and prevent being grazed because of the spines on its stems (Zhang et al., 2006a). As legumes, *C. microphylla* also contributes significantly to the nitrogen cycle through N_2 fixation (Li et al., 2013). For these reasons, *C. microphylla* is widely used as the pioneer species in vegetation reestablishment in the Horqin Desert to stabilize the shifting sand (Zhang et al., 2006b; Cao et al., 2011). With increasing sand-fixation year of *C. microphylla*, the density, height, cover and biomass of vegetations increase correspondingly (Zhao et al., 2007). The vegetations become strong drivers of the structure and function of soil food webs. Feedback and interaction between plants and soil can greatly influence soil biota communities (Kardol et al., 2006; van der Putten et al., 2013).

The soil nematode assemblage as an important component of soil biota communities is an ubiquitous inhabitant in soil

* Corresponding authors at: Institute of Applied Ecology, Chinese Academy of Sciences, P. O. Box 417, Shenyang 110016, China. Tel.: +86 24 83970359; fax: +86 24 83970300.
E-mail addresses: zxk@iae.ac.cn (X. Zhang), liangwj@iae.ac.cn (W. Liang).

http://dx.doi.org/10.1016/j.ecoleng.2015.04.011
0925-8574/

ecosystem (Pen-Mouratov et al., 2003). They occupy a central position in the detritus food web and can regulate the rates of decomposition, mineralization and nutrient cycling (Neher, 2001; Yeates, 2003; Bakonyi et al., 2007). Soil nematodes are also good indicators for evaluating soil food web structure and function because of their close relationship with soil environment and sensitivity to habitat disturbance (Neher, 2001; Wasilewska, 2006). Although the bioindication of soil nematode communities is very important for evaluating sand restoration, more attention is paid to plant community development during the restoration process (Zhang et al., 2005; Klass et al., 2012). Restoration of plant communities is of limited indicative value for belowground community development, because successful vegetation restoration does not necessarily indicate successful restoration of belowground biodiversity (Kardol et al., 2005; Parfitt et al., 2010). Korthals et al. (2001) and Hedlund et al. (2003) proposed that the belowground responses to the ecosystem restoration were slower than the aboveground due to different response rates between plants and soil organisms. Zhi et al. (2009a) reported that soil nematode abundance increased significantly after stabilizing sand dunes for 16 years. Jiang et al. (2007) reported that soil nematode was significantly higher under the canopy of the *C. microphylla* in 5-year-old plantations than that in drifting sand dune without vegetation cover at 0–10 cm depth. Klass et al. (2012) proved that soil nematode communities could indicate plant–soil interactions associated with desertification. Therefore, assessing the impact of vegetations on soil biodiversity restoration requires information on belowground community composition in order to establish proper conservation measures for restoration sites (Kardol et al., 2005).

Our objectives are to investigate the response of soil nematode community composition and diversity of the *C. microphylla* with different sand-fixation years, to analyze the effect of sand-fixation year and soil environment on soil nematode communities during restoration process, and to utilize soil nematodes as bioindicators to evaluate the contribution of sand-fixation vegetations to control desertification.

2. Materials and methods

2.1. Study site

This study was conducted at the Wulanaodu Experimental Station of Desertification (43°02′N, 119°39′E), Institute of Applied Ecology, Chinese Academy of Sciences. The station is located in western Horqin Desert of Northeast China, with a mean annual temperature and rainfall of 6.3 °C and 340 mm, respectively. The annual mean wind velocity ranges from 3.2 to 4.5 m s^{-1}. The soil is classified as Cambic Arenosols (IUSS Working Group WRB, 2007). The landscape is characterized by drifting, semi drifting and stabilized sand dunes (Jiang et al., 2007). Sand dune movement, wind erosion, and sand burial are frequent in this area. In addition, due to long-term overgrazing and overcutting, the original vegetation has been greatly changed over the past decades. Now the dominant vegetations are *C. microphylla*, *Bassia dasyphlla* and *Pennisetum flaecidum*.

2.2. Experimental design and sampling

C. microphylla, as the main sand-binding vegetation, has been gradually planted on sandy land in the Wulanaodu Experimental Station of Desertification since 1980s. The 0-year (the control without vegetation), *C. microphylla* shrubs with different sand-fixation years (13, 18 and 29 years) and natural *C. microphylla* shrubs were selected as five experimental treatments (hereafter called 0-Y, 13-Y, 18-Y, 29-Y and N-Y). For each treatment, four (20 m × 20 m) plots were selected randomly as four sample replicates. From each plot, composite soil samples of 3 sub-samples were collected under three *C. microphylla* shrubs with similar growth conditions (or without shrubs in CK) as one replication. After removing the surface residue, soil samples (about 1000 m^3) were taken at the 0–10 cm soil layer under the canopy of the shrub using a shovel in May 2013. Large roots and other debris were removed. All the samples were put into individual plastic bags and were kept at 4 °C until further analyses.

2.3. Analysis of soil physicochemical properties

Soil moisture (SM) was determined gravimetrically by drying samples at 105 °C for 48 h. Soil pH and electrical conductivity (EC) were measured in a soil–water suspension (1:2.5 and 1:5 soil–water ratio, respectively) with pH and conductivity meter (Thermo Fisher Scientific Inc., USA). Total soil organic carbon (TOC) was determined by potassium dichromate heating method and total nitrogen (TN) by Kjeldahl method (McGill and Figueiredo, 1993; Rowell, 1994).

2.4. Soil nematode extraction and identification

Nematodes were extracted from 200 g of fresh soil by a modified cotton–wool filter method (Liang et al., 2009). Nematode abundance was expressed as individuals per 100 g dry soil. 100 nematodes from each sample were identified to the genus level using an inverted compound microscope. If the total number was less than 100, all of the nematodes were identified. The nematodes were assigned to the following trophic groups characterized by feeding habits: bacterivores (BF), fungivores (FF), plant parasites (PP) and omnivores-predators (OP) (Yeates et al., 1993). Nematode life-history groups with *cp* (colonizer–persister) 1–3 were regarded as *r*-strategists and *cp* 4–5 as *K*-strategists (Bongers, 1990; Ferris et al., 2001). The nematode community indices were calculated as follows: dominance (λ), Shannon–Wiener diversity (H'), evenness (J'), richness (SR), plant parasite index (PPI) and plant parasite index/maturity index (PPI/MI) (Bongers et al., 1997; Yeates and Bongers, 1999).

2.5. Statistical analysis

Nematode abundance was $\ln(x+1)$ transformed prior to statistical analysis for normality of data. One-way ANOVA was used to evaluate the difference significance of environmental or nematode parameters among different sand-fixation years. Tukey's post hoc test was used to compare individual values among different sand-fixation years. All statistical analyses were performed by SPSS statistical software (SPSS Inc., Chicago, IL, USA). Difference at $P < 0.05$ level was considered to be statistically significant. Redundancy analysis (RDA) using CANOCO software was performed to analyze the relationship between soil nematode communities and sand-fixation year (ter Braak, 1988). Sand-fixation year was treated as nominal (0, 1) environmental variable. In order to find indicative genera to different sand-fixation years, predict on ratings were explored in our study according to RDA. The criteria of predicting ratings of nematode to different sand-fixation years were used as followed: a genus vector in RDA within the range of 45° close to the environmental variable vector was rated as positive correlation; a genus vector in RDA in the diagonally opposite quadrant was rated as negative correlation; if the genus did not fit neither of two criteria, it was regarded as no correlation (Zhao and Neher, 2013). To analyze the relationship between environmental parameters and nematode communities, the bioenv method (R-3.0.2 project) was employed using the Spearman correlation coefficient (Clarke and Ainsworth, 1993; R Development Core Team, 2006).