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Community structure of soil nematodes under different drought conditions

Dengming Yan[a,b], Denghua Yan[b], Xinshan Song[a], Zhilei Yu[b], Dou Peng[b], Xu Ting[b], Baisha Weng[b,*]

[a] College of Environmental Science and Engineering, State Environmental Protection Engineering Center for Pollution Treatment and Control in Textile Industry, Donghua University, Shanghai 201620, China
[b] Department of Water Resources, China Institute of Water Resources and Hydropower Research, Beijing 100038, China

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ABSTRACT

The study aims to investigate the effects of different drought treatments on the distribution of soil nematode community under the background of global warming. Light drought, moderate drought, severe drought treatments and control plot were set in the experiment. Experimental results showed that a total of 32 genera of nematodes from 18 families were identified under the four drought treatments, including 13 genera of bacterivores, 10 genera of plant-parasites, 4 genera of fungivores and 5 genera of omnivores-predators. *Eucephalobus* and *Helicotylenchus* were dominant genera under drought treatments. The quantity, genera and diversity of soil nematodes in drought treatments were significantly lower than those in control plots. The structure of the nematode community degenerated and the role of nematodes in soil food web was weakened in the agro-ecosystem after long-term drought. The study provides soil zoological basis for agro-ecosystem responding to extreme drought under climate change.

1. Introduction

Under the background of global warming, the occurrence frequency, intensity and extent of drought present an increasing trend over many agricultural areas, especially in North China (Dai, 2011; Mishra and Singh, 2010; Yang et al., 2014). Drought is one of the common natural disasters and has gained wide attention. Drought significantly affects the soil moisture, and the relative abundance and biodiversity of microbial community, thus altering the microbial functions of agro-ecosystem(Hueso et al., 2012). Previous studies on drought mainly focused on the productivity of crops affected, such as wheat, soybean and vegetable (Barba et al., 2016; Han and Yan, 2013; Rigby et al., 2016; Strauss et al., 2013). The variation of precipitation distribution influences the wheat agro-ecosystem in different soil types (Tataw et al., 2016). Soil nematodes are representative animals of farm soil animals, so we carried out research on soil nematodes selected as the object of study.

Soil nematodes can be divided into various taxonomic/functional types (Zhou et al., 2016) and > 500 different nematode species, including at least seven functional types (plant feeding nematodes, plant-associated nematodes, fungal hyphae-feeding nematodes, bacterial feeding nematodes, animal-parasitic nematodes, omnivorous nematodes, and unicellular eukaryotes nematodes) have been reported (Gaugler, 1987; Yeates et al., 1993b; Yeates et al., 1999). These functional types can sensitively respond to a variety of cultivation, fertilization, pesticides and water contents (Kalinkina et al., 2016). However, due to extensive application of pesticides and fertilizers, the relative abundance and biodiversity of nematodes significantly decrease in the agro-ecosystem (Majić et al., 2010; Ulu et al., 2016). In addition, the effects of different drought treatments on soil nematode community structure in the agro-ecosystem were seldom reported.

Nematodes are an effective bio-indicator for the responses of the agro-ecosystem to drought events under climate changes. In this study, under three different drought treatments, the biodiversity of species, trophic treatments, and functional structures of soil nematodes were investigated. Meanwhile, the natural climate condition was also set as the drought control system. Soil nematodes were classified and then assessed with various ecological indices.

2. Methods

2.1. Study area

The experiment was conducted at the Hydrological Experiment Station of Wudaogou (33°09′N, 117°21′E), Anhui Province, China (Fig. 1). The region experiences a sub-humid warm temperate continental monsoon climate with a mean annual precipitation of 704.2 mm and mean annual temperature of 14.7 °C. This region belongs to the typical agro-ecosystem associated with winter wheat. Winter wheat was sown in late October and harvested in June of the next year.

* Corresponding author.
E-mail address: baishaweng@163.com (B. Weng).

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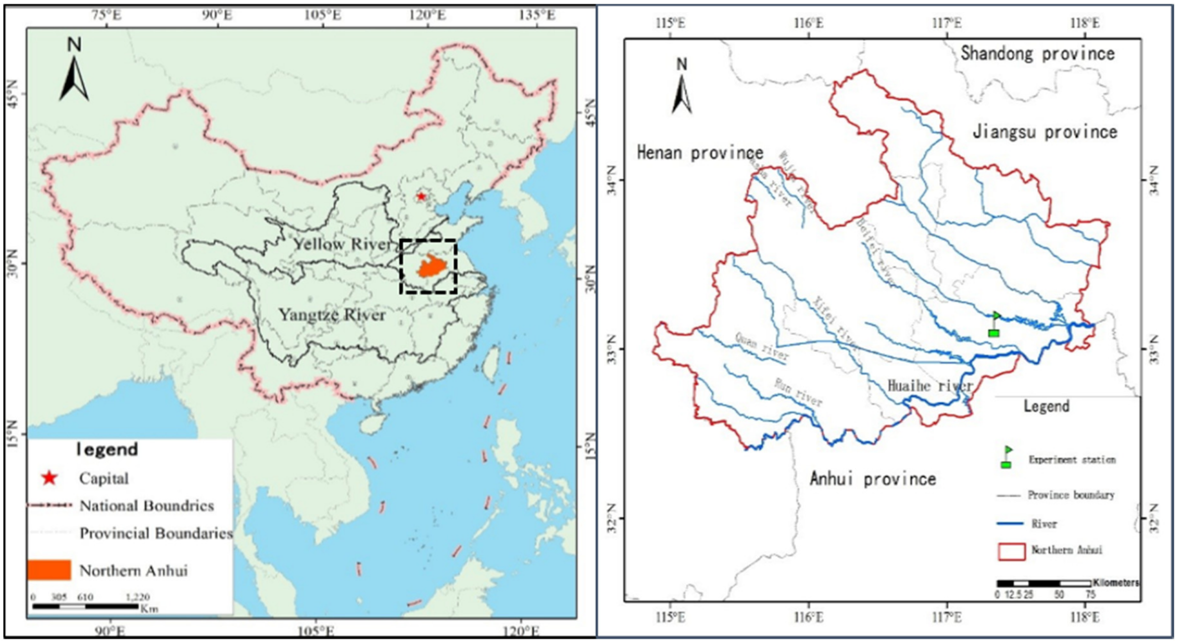

Fig. 1. The geographical location of Northern Anhui and Experiment station.

The main soil type of this region is Mortsar Black Soil. Soil contains 17.67 g kg^{-1} soil organic matter, 74.7 mg kg^{-1} available nitrogen, 15.6 mg kg^{-1} available phosphorus, and 247.1 mg kg^{-1} available potassium.

2.2. Experimental design and experimental conditions

Consecutive rainless days are an indicator for drought which has continuous non-effective rainfall days, so consecutive rainless days is a common index of drought. According to the statistical data of consecutive rainless days in Anhui Province (Table 1), four drought treatments (control plot, light drought, moderate drought, and severe drought) were designed to investigate the effects of drought on soil nematode community structure. The consecutive rainless days of light drought (LD), moderate drought (MD) and severe drought (SD) were respectively 15 days, 30 days, and 45 days. In particular, a control system (CK) was operated under the natural climate conditions. All the tests were conducted in the growth period of winter wheat. Totally 12 experimental plots (Length × Width = 4 m × 4 m) were designed and divided into 4 treatments to respectively simulate the CK, LD, MD, and SD treatments. Each drought treatment had 3 replicates. Stainless steel baffle was used to prevent external water, fertilizers and other soil animals. Drought treatments were sheltered under a ventilation shed to prevent external precipitation and simulate consecutive rainless conditions.

2.3. Soil sampling and nematode identification

All soil nematode samples were collected in the growth season of winter wheat (Liang-Nong 66) from April to June in 2015. Soil was sampled randomly at the 0–15 depth at typical sites, and mixed carefully to obtain a total of 36 composite samples. Stone, larger roots and macro-arthropods were excluded by hand. The soil samples were placed in the sealed plastic bags and immediately stored in the fridge at 4 °C. All the soil samples were preliminarily processed within a week.

The nematode population was extracted from a soil sample (100 g) according to Baermann Funnel Procedure (Sasser, 1962). After an extraction of 48 h, nematodes were preserved in 4% formaldehyde, counted, and then adjusted to 100 g dry soil. The abundance of nematodes is expressed as the quantity of nematodes per 100 g dry soil. Soil nematodes were counted and identified under an inverted compound microscope (Zhong et al., 2016).

Table 1
Drought index system in Anhui province.

Degree of drought	LD (light drought)	MD (moderate drought)	SD (severe drought)
Consecutive rainless days	10~20	20~40	40~55

2.4. Ecological indices

Based on the feeding habits, stoma and esophageal morphology, all the extracted soil nematodes were assigned to four trophic treatments (Yeates et al., 1993a, 1993b): *Bacterivores* (*Ba*), *Fungivores* (*Fu*), *Plant-parasites* (*PP*) *and Omnivore-predators* (*OP*). The classification of nematode colonizer-persister (*c-p*) value was performed based on life history strategies (Bongers, 1990; Bongers and Bongers, 1998). The characteristics of nematode community were assessed with the following ecological indices:

a) Shannon-Weiner diversity index, H′ (Mulder et al., 2005), $H' = -\sum Pi(\ln Pi)$;

b) Evenness index, J (Mulder et al., 2005), $H' = H'/\ln(S)$;

c) Simpson index, λ (Mulder et al., 2005), $\lambda = \sum Pi^2$;

d) Nematode channel ratio, NCR (Yeates, 2003a), NCR = Ba/(Ba + Fu);

e) Maturity index, MI (Yeates et al., 1993a), $MI = \sum (c - pi)vi'$;

f) Plant parasite index, PPI (Yeates et al., 1993a), $PPI = \sum (c - pi) vi'$;where *Pi* represents the proportion of each taxon in the total population; *c-pi* is the *c-p* value for the free-living nematodes to the *i*-th nematode genus; *vi*' indicates the proportion of the genus in the nematode community.

According to faunal methods, the formula is as follows: Enrichment index, EI = 100 (e / (e + b)), which is used to assess the food web response to the available resources; Structure index, SI = 100(s/(s + b)), which is used to indicate changes in the structure of soil food web under interference(Ferris et al., 2001).

where e is the abundance of individuals in guilds in the enrichment component weighted by their respective k_e values, b is the abundance of