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Response of nematodes to agricultural input levels in various reclaimed and unreclaimed habitats

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ABSTRACT

An analysis of nematode communities was conducted in two groups of habitats at the Quzhou Experimental Station of China Agricultural University. Saline–alkali land (SA) and wild woodland (WW) represented unreclaimed habitats (URE) without any agricultural input. Reclaimed habitats (RE) comprised artificial woodland (AW), orchard (OR), farmland (FA) and a greenhouse (GH), which represented increasing agricultural input level. Generally, the means of the ecological indices between unreclaimed and reclaimed habitats suggested that the reclamation of saline–alkali land increased nematode diversity. In the farmland and orchard, mid-levels of fertilizer input increased nematode diversity (Shannon index (H') and diversity of trophic groups (TD), respectively), whereas high levels of fertilizer input decreased nematode diversity (H') in the greenhouse. The pattern result of maturity index (MI) and maturity index for nematodes with cp2-5 (MI25) indicated that high input in the greenhouse with a high relative abundance of enrichment opportunists increased the difference of disturbance between unreclaimed and reclaimed habitats. Canonical correspondence analysis (CCA) results corresponded to the β_T index, which suggested that subsequent human activities (from low to high input) exerted greater influences on nematode communities than did soil reclamation (from no input to low input).

1. Introduction

To meet the growing human demand for resources and development, land transformation had been undertaken worldwide for the past several centuries. For instance, forests and grasslands were changed into farmland for crop production [1], and saline–alkali land was reclaimed for developing agriculture [2]. Alteration of land use and ground cover, accompanied by natural factors, changes the ecological processes of a habitat [3,4]. Additionally, soil organisms, as the most active component within the belowground ecosystem, also respond actively to environmental changes in the soil [5–9].

Nematodes, which are the most abundant metazoan among the soil biota, are widely distributed in all types of habitats [10] and occupy a central position in the detritus food web [11]. They play critical roles in the decomposition of soil organic matter and nitrogen mineralization [12]. Additionally, nematode communities are good indicators of soil health because of their sensitivity to environmental change [8,10,13]. Various nematode ecology indices, such as the diversity index, the ratio of fungivores to bacterivores, the maturity index and faunal analysis, can approximately indicate changes in the soil environment, which helps us to understand the effects of human activities on soil fertility, decomposition pathways and the condition of the soil food web [8,14–17].

Quzhou County in the upper Heilonggang region was historically an inland alluvial plain [18] with saline phreatic water and widespread soil salinization, which resulted in a barren soil condition and low crop yield [2]. Since soil reclamation began in 1973, the soil quality in this area has gradually improved, and various land management practices using different input intensities have led to a few stages of soil ecosystem succession. We conducted this research to answer the following questions: Have the nematodes in these soils been affected by reclamation and input? Will the nematode communities respond consistently to the gradient of farming intensity?

In this study, we identified two groups of habitats. Group one comprised two unreclaimed habitats. One was in the original state of saline–alkali land, and the other was in a relatively natural succession phase. Group two consisted of reclaimed habitats and generally represented the main local land use types with different

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Table 1
Details of management in different habitats.

Habitat	Input level	Fertilizer (application rate, t ha^{-1})	Fertilizer composition	Pesticide	Plots size (m^2)
SA	No	–	–	–	24.7
WW	No	–	–	–	197.7
AW	Low	–	–	–	411.8
OR	Medium	Humic acid compound (2.25)		Insecticides and fungicides	1666.7
FA	Medium	Chemical (1.80)	Urea, ammonium bicarbonate and calcium super-phosphate (1:2.5:2.5)	Insecticides	31.5
GH	High	Organic (22.60)	Livestock dung, straw, cotton-pressed trash and bran (6:12:1:1)	Insecticides and fungicides	60.7
		Chemical (3.00)	Urea, potassium sulfate and calcium super-phosphate (3:4:5)		

agricultural input intensities. Overall, the objective of the study was to use soil nematodes as indicators to reflect the effects of soil reclamation and the strength of human disturbance on the condition of the soil.

2. Materials and methods

2.1. Study site

The experimental site was located at the Quzhou Experimental Station of China Agricultural University in the North China Plain (36°52′N and 115°01′E). The station is in a continental temperate monsoon zone with a warm and semi-humid climate and consists of summer rainfall and dry-cold winters. The mean annual temperature is 13.2 °C, and the mean annual precipitation is 542.7 mm. The soil type of this region is an improved silt fluvo-aquic soil [19].

The study areas were divided depending on whether the soil had been reclaimed.

One comprised two habitats: Saline–alkali land (SA) and wild woodland (WW); both were unreclaimed habitats (URE) without any human input. The saline–alkali land was distant from the experimental station and had remained in the original state of saline–alkali soil without disturbance. *Eragrostis pilosa*, *Digitaria sanguinalis* and *Erodium stephanianum* were the dominant plants in this area. However, the vegetation coverage was low. The wild woodland was inside the boundaries of the experimental station and also near human residences. With little influence from human daily life, the dominant vegetation was herbs and bushes, including *Phragmites australis*, *Salsola collina* and *Ulmus pumila*.

The second comprised artificial woodland (AW), orchard (OR), farmland (FA) and a greenhouse (GH), which were all reclaimed habitats (RE) with varying agricultural input levels. The artificial woodland was planted with *Populus tomentosa* Carr in 1981, and the dominant ground floor vegetation was *Lagopsis, Roegneria ciliaris* and *Robinia pseudoacacia*. This habitat represented low or no input. The apple (*Malus pumila*) orchard was established in 1992 with the application of humic acid compound fertilizer. The dominant ground floor vegetation in the orchard was *Plantago asiatica*, *Solanum nigrum* and *Humulus scandens*. Before our first soil sampling (June 2009), a lot of pesticides were used in the orchard. The farmland was a long-term chemical fertilizer experiment established in 1993, with an annual rotation of winter wheat (*Triticum aestivum*) and summer maize (*Zea mays*). Both orchard and farmland represent the local medium input. The greenhouse, which represented high input intensity, was also a long-term experiment launched in 2002. The greenhouse was constructed of clay walls and covered with polyethylene film. Conventional management was applied to the greenhouse with organic fertilizer and chemical fertilizer, and chemical methods were used for pest control. During the study period, tomatoes (*Solanum lycopersicum*) were planted in the field. Pesticides were used from the end of May to early June. The orchard, farmland and greenhouse had the same soil history, which is that they were farmlands with an annual rotation of winter wheat and summer maize before the present land-use.

2.2. Soil sampling and analysis

In our initial experiment design, the saline–alkali land was not considered. After all experiment work, we realized a real saline–alkali habitat was needed, and there might be small year-to-year variations in the soils of this habitat. Hence, the sampling was first conducted in WW, AW, OR, FA and GH (in June and October 2009), then sampling in SA was conducted in October of the next year (2010). In the farmland, the habitat was divided randomly into three plots, and we took two samples from each plot. In the other habitats, each habitat was divided into six plots from which one sample was taken from each plot. Each sample comprised five soil cores (0–20 cm in depth, 2.5 cm in diameter) in a zigzag pattern that were thoroughly mixed and placed in individual plastic bags and then immediately transferred to a 4 °C cold room. Root fragment and other organic debris were removed from each sample, and subsamples for chemical analysis were sieved through a 2 mm sieve.

Soil organic matter was measured using the oxidation of potassium dichromate with a 0.4 mol L^{-1} $K_2Cr_2O_7$–H_2SO_4 solution. The total N of the soil was measured by Kjeldahl digestion. The available soil P (only in October 2009, 2010) was measured with the molybdate blue colorimetric method. The available K in the soil was determined using the flame emission spectrometry method. The pH (soil: H_2O ratio 1:2.5) was measured with a glass electrode. Electric conductivity (only in October 2009, 2010) was determined by a conductivity meter in a 1:5 soil:water solution (w/v). The soil water content was determined by drying samples at 105 °C for 48 h.

2.3. Nematode extraction and identification

Nematodes were extracted from 100 g of soil sample (fresh weight) by a sugar flotation and centrifugation method [20]. Nematode abundance was expressed per 100 g of dry soil. After counting the total number of nematodes, at least 100 nematodes were identified to genus using an inverted compound microscope.

2.4. Data analysis

Nematodes were classified into four trophic groups by feeding habits, i.e., bacterivores (Ba), fungivores (Fu), plant feeders (PP) and omnivore–carnivores (Om–Ca) [21]. The nematode community was described by the following ecology indices: