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Original article

Effect of desert plant ecophysiological adaptation on soil nematode communities

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ABSTRACT

Nutrient source limitation in desert ecosystems enhances competition among plant communities, leading to creation of microhabitats beneath the shrubs that can determine composition and abundance of soil organisms. The aim of the study was to determine the effect of plant ecophysiological adaptation on soil nematode communities in the rhizosphere of tightly interweaving shrubby communities. Soil samples were collected monthly under the canopies of three perennial desert shrubs: *Artemesia herba-alba*, possessing the allelopathic ability to dominate in relationships with other plants; *Reaumuria negevensis*, a salt-resistant plant; and *Noea mucronata*, a typical dry desert shrub. An inter-plant area was used as a control. The results demonstrated that soil water content (SWC) and total organic carbon (C_{org}) were significantly different under different plants and inter-plant areas, with the highest values found under *R. negevensis* (SWC) and *N. mucronata* and *R. negevensis* (C_{org}). Plant parasite and omnivore-predator nematodes were more sensitive to the ecophysiological individual features of observed plants versus the total number of nematodes and bacteria- and fungi-feeding nematodes. Generally accepted ecological indices such as Wasilewska (WI), trophic diversity (T), maturity (MI, MMI), basal (BI), enrichment (EI), structure (SI), and channel (CI), pointed to specific ecological conditions under canopies of the observed plants.

1. Introduction

The plant rhizosphere is one of the most important habitats for soil micro-organisms [1,4], including primary herbivores such as fungi, bacteria, nematodes and their consumers [33]. The activity of soil micro-fauna in desert soils is dependent on soil temperature and moisture, and the availability of organic carbon [31,37,50,57].

Arid and semi-arid regions are characterized by marked patchiness in vegetation distribution [3,41,47,50], where trees and shrubs implement function as "keystone species" [12], producing "nutrient islands". Moreover, the physical and chemical components of the desert environment, including salinity, water, and organic availability, determine the nature of the vegetation [16]. On the one hand, abundance and distribution of soil biota populations are found to be in close positively correlated dependence on these "nutrient islands" [39]. On the other hand, the macrophytic patches are limited by a nutrient resource [14] that leads to competition between plant communities [25,60], including allelopathic interactions [20,40]. The complex of external and internal interactions forcing the ecophysiological mechanism of plants to change

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can also affect soil organisms. Of all soil organisms, nematode communities possess several attributes that turn them into the best indicators for evaluation of soil conditions [19,34,66].

Numerous publications indicate that some plants or plant extracts can reduce root-knot nematode populations [9,28,42,44]. These investigations focused mainly on agricultural areas. However, to our knowledge, information on the allelopathic influence on soil nematode communities is still quite limited. Along with traditional ecological indices of nematode community structure such as Wasilewska, maturity, plant parasite, Shannon-Weaver, etc., which are in widespread use for the detection of environmental changes, several new ecological indices such as structure index, enrichment index, basal index, and channel index [17,18,27], have become popular during the last few years.

The aim of the present study was to determine the effect of plant ecophysiological adaptation on soil nematode communities in the shrub rhizosphere. Plots in the Negev Desert ecosystem having tightly interweaving shrubby communities including widespread desert species such as *Artemisia herba-alba*, *Reaumuria negevensis*, and *Noea mucronata* [15], were chosen. *A. herba-alba* is known as a species that uses allelopathic ability to dominate relationships with other plants [21] and depresses soil organisms in the rhizosphere [23]. *R. negevensis* is resistant to high salinity, and *N. mucronata* is a typical dry desert shrub [16].

2. Materials and methods

2.1. Study site

The study site is located on the northern rocky slope of the Negev Desert, near Sede Boqer (30°50′N:34°46′E) in the central Negev region of Israel. The altitude of the slope is ca. 30 m. The area is arid, with highly variable winter rains (about 100 mm annually), and is sparsely vegetated with permanent shrubland [16]. The slope is covered with *A. herba-alba*, *R. negevensis*, and *N. mucronata*, which are typical Negev Desert shrubs [10,16].

A. herba-alba Asso. (*Artemisia inculta* Del) is one of the dominant dwarf shrubs in the Negev Desert [15]. On the north-facing slopes, the strongly aromatic sagebrush *A. herba-alba* may account for approximately 70% of the individuals in the plant association [21]. *A. herba-alba* has a pronounced allelopathic ability to inhibit the germination of some plants [13,21]. *R. negevensis* (Tamaricaceae) shrub is a perennial plant with succulent leaves which grows mainly in salty habitats and belongs to the Xerohalophytes [11,16]. *Noea mucronata* also belongs to the Xerohalophytes and is the co-dominant plant over large areas of the Judean and Negev Deserts [11].

2.2. Sampling

A total of 208 soil samples were collected between October 2002 and November 2003 from the upper (0–10 cm) soil layer under the canopies of *A. herba-alba*, *R. negevensis*, and *N. mucronata*. Four sample replicates, each 0.5 kg in weight, were collected monthly from under every plant. The area between the shrubs served as control. Soil samples were deposited in individual plastic bags which were placed in an insulated container and taken to the laboratory. These soil samples were kept in cold storage at 4 °C until processed. They were sieved (2 mm mesh size) before biological and chemical analyses in order to remove root particles and other organic debris.

2.3. Laboratory analysis

The following analyses were performed on each sample:

1. *Soil water content* (SWC) was determined gravimetrically as a percentage of dry mass by drying the samples to a constant weight at 105 °C.
2. *Total organic carbon* (C_{org}) was determined using a modified method of Rowell [43].
3. The nematode population was determined by extraction from 100 g fresh soil samples using the Baermann funnel procedure [8]. The recovered organisms were counted using a compound microscope and preserved in formalin. The nematodes from each sample were collected and identified according to order, family, and genus using a compound microscope. Nematodes were classified according to known feeding habitats or stoma and esophageal morphology [37,53] into the following trophic groups [64]: (1) bacteria-feeding; (2) fungi-feeding; (3) plant parasites; and (4) omnivore-predators. The total number of nematodes was counted and adjusted to 100 g dry soil.

2.4. Ecological indices and statistical analysis

The characteristics of the nematode communities were described using the following indices: (1) absolute abundance of individuals adjusted to 100 g^{-1} dry soil (TNEM); (2) abundance of omnivore-predator (OP), plant-parasitic (PP), fungi-feeding (FF) and bacteria-feeding (BF) nematodes (trophic structure) [30,52,53]; (3) $WI = (FF + BF)/PP$ [58]; (4) fungivore/bacterivore (F/B) ratio, $F/B = FF/BF$ [55]; (5) trophic diversity (T), $T = 1/\sum P_i^2$, where P_i is the proportion of the ith trophic group [26]; (6) Simpson's dominance index (λ), $\lambda = \mathrm{Sum};P_i^2$ [49]; (7) Shannon-Weaver index (H'), $H' = -\sum P_{il}(\ln P_{il})$, where P is the proportion of individuals in the ith taxon [48]; (8) maturity index (MI), $MI = \sum \upsilon_i f_i/n$, where υ_i is the c–p value assigned by Bongers [6,7] of the ith genus in the nematode, f_i is the frequency of family "i" in sample and n is total number of individuals in a sample [35]. The c–p values describe the nematode life strategies, and range from 1 (colonizers, tolerant to disturbance) to 5 (persisters, sensitive to disturbance); (9) plant parasite index (PPI) [6]; (10) maturity index modification (MMI), including plant-feeding nematodes [62]; (11) species richness, $SR = (S - 1)/\ln(N)$, where S is the number of taxa and N is the number of individuals identified [65]; (12) basal index $(BI) = 100 \times (b/(b + e + s))$; (13) channel index $(CI) = 100 \times 0.8 \times Fu_2/(3.2 \times Ba_1 + 0.8 \times Fu_2)$; (14) enrichment index $(EI) = 100 \times (e/(e + b))$; and (15) structure index $(SI) = 100 \times (s/(s + b))$, where $b = 0.8 \times (Fu_2 + Ba_2)$; $s = 0.8 \times Ca_2 + 1.8 \times \sum(X_3) + 3.2 \times \sum(X_4) + 5.0 \times \sum(X_5)$; $e = 3.2 \times Ba_1 + 0.8 \times Fu_2$ [17,18,27,29].

All data were subjected to statistical analysis of variance using the SAS model (ANOVA, Duncan's multiple range test, and Pearson correlation coefficient) and were used to evaluate