DOI 10.2478/s11687-007-0032-6

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HELMINTHOLOGIA, 44, 4: 204 – 209, 2007

Soil nematode community structure in a Chinese sand dune system

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Summary

Soil nematode community structure was studied in a terrestrial sand dune system of the Horqin Sandy Land, Northeast China. The nematode abundance and generic composition in four sites (from the lowland, the middle part of windward slope and the top of windward slope to leeward slope) and three soil layers (0 – 20 cm, 20 – 40 cm and 40 – 60 cm) of the stabilized sand dune were compared. The results showed the total number of nematodes which ranged from 11 to 160 individuals per 100 g dry soils was significantly different among the sites and the depths ($P < 0.05$). Thirty genera were observed and *Acrobeles* was the dominant genus in our investigation. A significant difference in the abundance of bacterivores was found among the depths ($P < 0.01$). The total numbers of nematodes and plant parasites positively correlated with electronic conductivity, soil moisture, total organic carbon and nitrogen contents ($P < 0.05$). S, TD, NCR and PPI were found to be sensitive to environmental stress in the stabilized sand dune system.

Key words: soil nematode; community structure; ecological indices; sand dune system

Introduction

Soil nematodes occupy a central position in the detritus food web and we can obtain much information on soil environmental change through analyzing the taxonomy and feeding characteristics of soil nematodes (Gupta & Yeates, 1997; Neher, 2001). Nematode community structure can be used as a good bioindicator in environmental monitoring because of nematodes' special traits which do not occur in other soil fauna (Bongers & Ferris, 1999). Some researches demonstrated that the abundance, diversity and species composition of soil nematode communities could reflect the variation of the disturbed environment (Panesar *et al.*, 2001; Háněl, 2003; Freckman &Virginia, 1997).
Goralczyk (1998) studied the bioindication of nematodes in a coastal dune and showed that the soil nematode community was a good indicator of the process of plant succession in dune hollows. Wall *et al.* (2002) found that the abundance, diversity, trophic structure and the composition of soil nematode communities were related to edaphic factors from sites along a coastal sand dune succession. But few studies were conducted on soil nematode community structure in a terrestrial sand dune. In arid and semi-arid environments, especially in a terrestrial sand dune, some factors such as soil moisture, soil organic carbon and wind erosion etc. played decisive roles in forming soil nematode community structure.
The objectives of our study were to investigate the nematode community structure in a stabilized sand dune system, to clarify the living mechanism of nematodes in terrestrial sand dune and to find the relationship between nematodes and soil properties through analyzing the distribution of nematodes in different sites and soil depths of the stabilized sand dune.

Materials and Methods

This study was conducted at the Wulanaodu Experimental Station of Desertification (42°29′ – 43°06′ N, 119°39′ – 120°02′ E), Chinese Academy of Sciences, Western Horqin Sandy Land, in Northeast Inner Mongolia, China. The annual temperature averages 5.1 ºC, mean annual precipitation is 340 mm and annual mean wind velocity ranges from 3.2 to 4.5 m s^{-1} (Liang *et al.*, 2007b). In most times, the direction of wind is northwestern (Jiang *et al.*, 2007).
A typical stabilized sand dune (42°59′ N, 119°39′ E) was selected in our study, which was 25 m in height. The stabilized sand dune system was composed of four parts: inter-

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dune lowland (Control), middle part of windward slope (A), top part of windward slope (B) and leeward slope (C). The interdune lowland was vegetated with *Eupatorium lindleyanum* DC., *Carex duriuscula* CA. Mey etc.; *Caragana microphylla* was the dominant plant species and was planted 24 years ago at site A and B, where vegetation cover was greater than 50%; there was a vegetation coverage less than 5 % at site C (Yan *et al*., 2005).

Soil samples from three soil layers (0 – 20 cm, 20 – 40 cm and 40 – 60 cm) were collected using a 5 cm diameter corer from the four sites (Control, A, B and C) on October 19, 2006. Four transects as four replications, each 10 m apart, were run through the sand dune system. A 5 m × 5 m quadrat was selected along each transect in each site. Composite samples were made up from five cores in a quadrat and mixed.

Nematodes were extracted from 200 g (fresh weight) of soil from each sample using the modified Cobb floatation method (Goralczyk, 1998). Soil physicochemical properties including soil moisture, pH, EC (electronic conductivity, determined by Thermo Orion 150 A+), TOC (total organic carbon) and TN (total nitrogen) at different sites and depths were determined (Jiang *et al*., 2007) and are shown in Table 1.

The abundance of nematodes was expressed per 100 g dry weight soil (Liang *et al*., 2007a). Nematodes were identified to genus level using an inverted compound microscope. The classification of trophic groups was assigned to: bacterivores (BF), fungivores (FF), plant parasites (PP) and omnivores-predators (OP), based on known feeding habitats or stoma (Yeates *et al*., 1993).

The ecological indices were calculated: S (Nematode taxon richness) (Ekschmitt *et al*., 2001), Shannon-Weaver diversity H' for genera, evenness J', dominance λ, trophic diversity TD (Yeates & Bongers, 1999), Maturity index MI (excluding plant parasites), Plant parasitic index PPI (only including plant parasites) (Bongers, 1990), and nematode channel ratio (NCR) (Yeates, 2003).

All data were subjected to statistical analysis of variance (ANOVA) in the SPSS statistical package.

Results

The total number of nematodes in different sites and depths ranged from 11 to 160 individuals per 100 g dry soil (Fig. 1). Significant difference in the abundance of total nematodes was found among sites and depths ($P < 0.05$), where 0 – 20 cm > 20 – 40 cm > 40 – 60 cm and Control > B > A > C. The numbers of total nematodes positively correlated with EC, soil moisture, total organic carbon and total nitrogen ($P < 0.001$) (Table 4).

Thirty genera of nematodes were identified in the stabilized sand dune system (Table 2). Except for in the control,

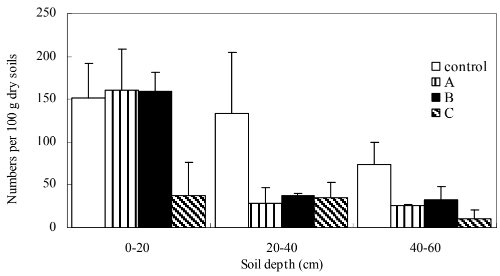

Fig.1. Abundance of total nematodes (mean ± SD) at different parts and soil depths of stabilized sand dune system

Acrobeles was dominant genus (the genus of nematode was dominant if its relative abundance was more than 10 %.) in other sites and their numbers were significantly different among the sites ($P < 0.01$). *Acrobeloides* was the dominant genus except at site C, but no significant difference in their numbers was found among the sites. The numbers of *Hemicycliophora* and *Filenchus* were significantly higher in the control than in other sites ($P < 0.01$), which showed that they were the special genera in the control. *Wilsonema* was the dominant genus at site C and

Table 1. Soil physicochemical properties at different parts and soil depths of stabilized sand dune system

Soil depth	Sites	TOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	pH	EC ($\mu s\ cm^{-1}$)	SM (%)
0-20 cm	Control	16.41	0.77	7.92	257.35	15.39
	A	5.12	0.19	5.79	50.03	0.45
	B	6.15	0.16	5.76	45.37	0.43
	C	2.94	0.13	6.54	32.05	0.45
20-40 cm	Control	6.95	0.32	8.20	132.00	7.37
	A	2.62	0.01	6.11	18.08	0.41
	B	3.50	0.04	6.15	19.53	0.39
	C	2.00	0.09	6.79	18.00	0.88
40-60 cm	Control	5.11	0.46	8.22	85.15	6.34
	A	2.49	0.00	6.05	18.53	0.42
	B	2.99	0.00	6.11	24.50	0.33
	C	2.51	0.06	6.78	17.25	0.65

Table 2. Mean relative abundance (%) of nematode genera at different parts of stabilized sand dune system

Trophic groups	Genera	c-p	Control	A	B	C	P-value
Bacterivores	*Acrobeloides*	2	14.15	13.71	10.03	7.45	NS
	Acrobeles	2	2.89	40.34	43.10	40.79	< 0.01
	Alaimus	4	1.31	2.50	4.35	0.20	< 0.05
	Cervidellus	2	0.79	17.85	14.63	3.49	< 0.01
	Chiloplacus	2	0.77	3.51	2.73	9.70	< 0.01
	Heterocephalobus	2	1.55	0.00	0.29	0.77	< 0.01
	Mesorhabiditis	1	5.93	0.00	0.00	0.61	< 0.01
	Plectus	2	1.29	1.56	5.01	0.50	< 0.05
	Prismatolaimus	3	1.78	0.06	0.23	0.75	NS
	Protorhabiditis	1	2.53	0.00	0.00	0.00	< 0.01
	Terotocephalus	3	0.70	0.00	0.00	0.00	< 0.01
	Wilsonema	2	1.73	7.37	6.95	10.87	< 0.05
Fungivores	*Aphelenchus*	2	2.12	2.33	0.34	1.10	NS
	Aphelenchoides	2	1.89	1.32	1.57	1.60	NS
	Tylencholaimellus	4	0.22	0.00	0.00	0.00	NS
	Tylencholaimus	4	2.31	1.70	2.11	1.41	NS
Plant parasites	*Criconemoides*	3	1.31	1.04	0.37	8.94	NS
	Dorylaimellus	5	0.98	0.16	0.13	0.13	NS
	Filenchus	2	35.33	0.40	0.10	1.10	< 0.01
	Geocenamus	3	0.51	3.43	5.13	0.00	< 0.01
	Helicotylenchus	3	0.27	0.00	0.16	5.22	NS
	Hemicycliophora	3	7.14	0.00	0.00	0.13	< 0.01
	Heterodera	3	0.62	0.00	0.00	0.39	NS
	Paratylenchus	2	0.13	0.00	0.00	0.33	NS
	Paratrichodorus	4	2.05	0.00	0.00	0.00	< 0.01
	Pratylenchus	2	0.94	0.00	0.00	0.00	< 0.05
Omnivores-predators	*Aprocelaimellus*	5	7.24	1.42	1.83	2.28	NS
	Discolaimus	5	0.25	0.17	0.12	1.22	< 0.05
	Epidorylaimus	4	0.13	0.00	0.00	0.00	NS
	Microdorylaimus	4	1.15	1.13	0.83	1.02	NS

Cervidellus was dominant at site A and B, but not in other sites. Significant differences in the number of *Cervidellus* were observed among the sites and the depths ($P < 0.01$).

Bacterivores were the most abundant trophic group at sites A, B and C and omnivores-predators were the least (Fig. 2). Significant difference in the number of bacterivores was found between the depths ($P < 0.01$), but in the number of plant parasites, significant difference was observed among the sites ($P < 0.01$). Significant differences in the numbers of fungivores and omnivores-predators were found among the sites and the depths ($P < 0.05$). The numbers of fungivores, plant parasites and omnivores-predators positively correlated with EC, soil moisture, total organic carbon and total nitrogen ($P < 0.01$). The numbers of bacterivores negatively correlated with pH ($P < 0.05$), and those of plant parasites and omnivores-predators positively correlated with pH ($P < 0.01$) (Table 4).

Significant differences in S, NCR, TD, H', MI and PPI were found among the sites ($P < 0.05$), but not depths (Table 3). No significant differences in the values of evenness (J') and genus dominance (λ) were found among the sites and the depths. The highest value of S was found in the control. The same result also occurred in the values of TD. This proved that there were high richness and trophic diversity in lowland of stabilized sand dune. The lowest values of H' in three soil layers were present at site C. The

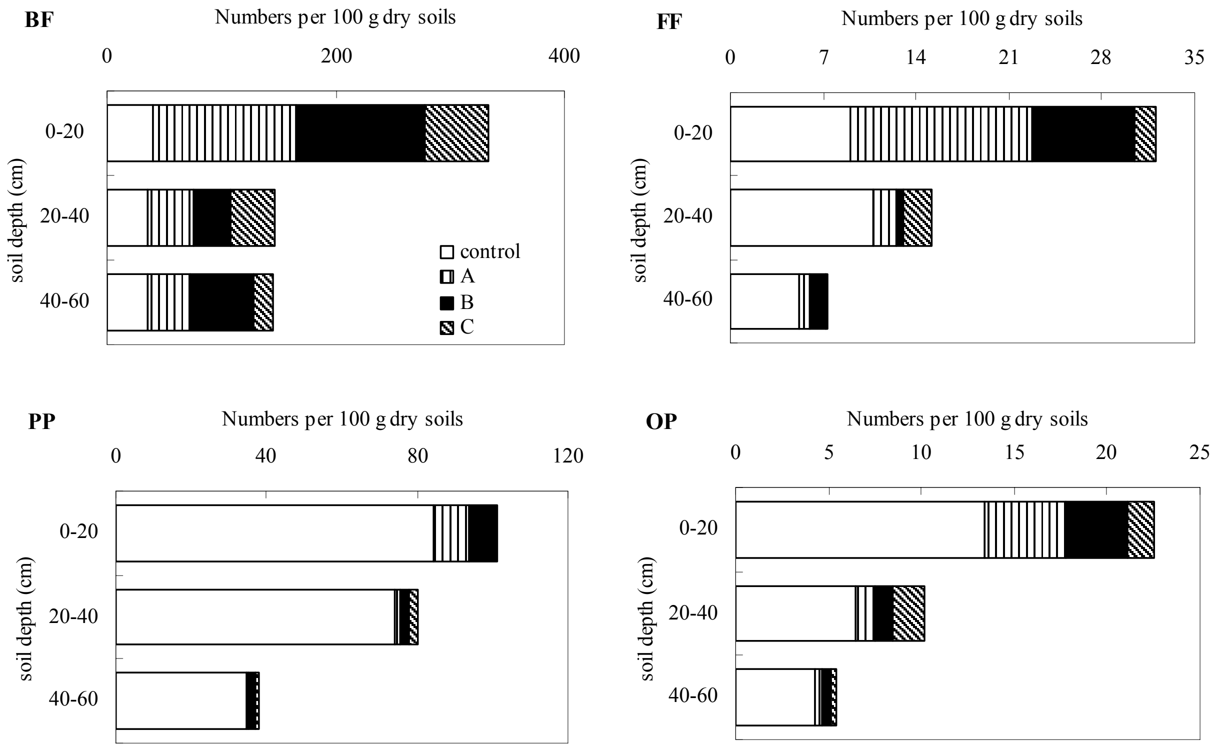

Fig.2. Abundance of four trophic groups at different parts and soil depths of stabilized sand dune system
BF-bacterivores; FF-fungivores; PP-plant-parasites; OP-omnivores-predators

values of NCR and PPI negatively correlated with EC, pH, soil moisture, total organic carbon and total nitrogen ($P < 0.05$), and those of S and TD positively correlated with EC, pH, soil moisture, total organic carbon and total nitrogen ($P < 0.05$). The value of J' negatively correlated with EC and the value of MI positively correlated with EC, pH and soil moisture ($P < 0.05$) (Table 4).

Discussion

In our investigation, soil properties were significantly different in the four sites, especially in the control (lowland). The feature of topography in lowland determined that there were high moisture and soil nutrients in that place (Lü *et al*., 2002).

Table3. Nematode ecological indices in different treatments

Soil depth	Sites	S	NCR	TD	λ	H'	MI	PPI	J'
0-20 cm	Control	14	0.38	2.39	0.32	1.73	2.64	2.29	0.65
	A	13	0.43	2.38	0.22	1.88	2.33	2.29	0.73
	B	12	0.47	2.56	0.30	1.80	2.44	2.62	0.81
	C	5	0.94	1.42	0.37	1.45	2.26	3.00	0.74
20-40 cm	Control	17	0.91	1.43	0.22	2.03	2.14	3.08	0.79
	A	10	0.98	1.14	0.24	1.76	2.07	2.50	0.76
	B	11	0.94	1.38	0.26	1.75	2.36	3.06	0.75
	C	11	0.91	1.34	0.31	1.65	2.17	3.00	0.75
40-60 cm	Control	16	0.95	1.22	0.15	2.24	2.12	2.97	0.70
	A	7	1.00	1.21	0.31	1.42	2.11	2.00	0.62
	B	9	0.69	1.52	0.30	1.52	2.23	2.73	0.80
	C	6	0.64	1.12	0.42	1.18	1.99	2.67	0.76

Table 4. Correlation coefficients for soil nematodes and soil chemical properties

Indicator	EC	pH	SM	TOC	TN
Tnem	0.615**	0.194	0.469**	0.659**	0.519**
BF	0.087	-0.317*	-0.077	0.198	0.131
FF	0.452**	0.130	0.417**	0.479**	0.301**
PP	0.828**	0.639**	0.764**	0.795**	0.682**
OP	0.461**	0.389**	0.572**	0.319**	0.325**
S	0.465**	0.524**	0.510**	0.362*	0.465**
NCR	-0.587**	-0.715**	-0.575**	-0.498**	-0.509**
TD	0.621**	0.744**	0.633**	0.455**	0.529**
λ	-0.026	-0.123	-0.112	-0.006	-0.091
H'	0.199	0.285	0.280	0.151	0.255
MI	0.365*	0.354**	0.468**	0.297	0.237
PPI	-0.553**	-0.557 **	-0.456**	-0.429*	-0.453**
J'	-0.315*	-0.075	-0.156	-0.283	-0.200

*, ** – Correlations are significant at $P < 0.05$ and 0.01 levels, respectively; EC-electronic conductivity; SM-soil moisture; TOC-total organic carbon; TN-total nitrogen; Tnem-total number of nematodes

The number of total nematodes was significantly higher in the control than in other sites. The most abundant trophic group in the control is plant parasite, but it was replaced by bacterivore at sites A, B and C. Omnivores-predator was the least common trophic group in our study. These results were not consistent with those reported by Wall *et al.* (2002), who found that omnivores were the dominant and bacterivore was the second dominant group within the nematode community in the sand dune system at the mouth of the river Tay. It can be concluded that the different results were produced by the variation of soil environment and plantation between terrestrial and coastal sand dunes.

Acrobeles was the predominant genus except for in the control, which was similar to that found in Danish sand dunes (Bussau, 1990). This result indicated that *Acrobeles* was the discriminative genus for lowland and other parts of stabilized sand dune system. Most of *Wilsonema* were found at site C, *Cervidellus* at site A and B, and *Filenchus* and *Hemicycliophora* in the control. We can assume that the change in the soil nematode community was produced by the soil environment, which was mainly determined the availability of food sources of nematodes such as bacteria and fungi, and some organic matter availability etc. (Freckman *et al*., 1987). Nematodes would migrate to their recognized habitat when the soil environment in which they lived changed and the preferable habitat of different genera of nematodes was discriminative. So the number and diversity of nematodes will vary with changes in the soil environment.

H' (Shannon-Weaver diversity) often reflects the diversity of the rare genera of a nematode community (Pen-Mouratov *et al*., 2003). In our study, the value of H' was significantly lower at site C than at other sites, which tested that the biodiversity of nematodes in different sites of stabilized sand dune system will be different significantly. The value of λ, showed an obviously increasing trend from the control to site C. The opposite result occurred in the value of S and TD, which proved that the diversity and stability of nematode community decreased at site C. The decrease of MI and the increase of PPI from the control to site C also indicated that the habitat for nematodes was more stable in lowland than at site C. These results were in agreement with that reported by Freckman and Ettema (1993), who found that the frequency of soil disturbance was inversely related to the MI but positively correlated with the PPI. The value of NCR in 0–20 cm was significantly higher at site C than at other sites, which indicated that the bacterial decomposition pathway was dominant in 0 – 20 cm of site C. The total numbers of nematodes and plant parasites positively correlated with EC, soil moisture, total organic carbon and nitrogen, which proved that these soil properties had positive effects on the nematode communities and were main factors affecting soil nematode community structure in sand dune system. Furthermore, the total numbers of nematodes and plant parasites were indicative of the changes in plant and soil restoration. S, TD, NCR and PPI correlated with EC, pH, soil moisture, total organic carbon and nitrogen and we can conclude that they are sensitive indicators for assessing nematode community in the stabilized sand dune system.

In our study, vegetation succession process at different stages was formed from the control (the lowland) to site C (the leeward slope). All these results showed that changes in soil properties during the process of vegetation succession were companied by corresponding changes in soil nematode community structure. The changes in nematode communities can indicate changes in a complex of soil properties (Goralczyk, 1998). We can demonstrate that the changes in soil nematode communities correlated with those of most soil physicochemical properties; soil nematodes were regarded as bioindicators to reflect the stability of the sand dune system.

Acknowledgements

This research was supported by the Natural Science Foundation of China (No. 30700109) and the Innovative Program of Institute of Applied Ecology, Chinese Academy of Sciences (06LYQY4001).

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RECEIVED APRIL 23, 2007

ACCEPTED AUGUST 2, 2007