Nematode Diversity in Phaeozem Agroecosystems of Northeast China*1

LI Qi1, JIANG Yong1, LIANG Wen-Ju1,∗2, WANG He2 and JIANG Si-Wei1

1Key Laboratory of Terrestrial Ecological Process, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016 (China)
2Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081 (China)

(Received March 6, 2009; revised July 20, 2009)

ABSTRACT

The diversity and distribution patterns of soil nematode communities in phaeozem agroecosystems of Northeast China were assessed to evaluate nematode taxonomic diversity and functional diversity in relation to climatic condition and soil characteristics in human modified landscape. Along the latitudinal gradient, soil samples were collected from north (Hailun) to south (Gongzhuling) down to a depth of 100 cm with intervals of 0–20, 20–40, 40–60, 60–80, and 80–100 cm. The nematode abundance and taxonomic diversity (generic richness) were lower at Hailun than at other sites, and higher values of evenness were observed at Hailun and Harbin than at Dehui and Gongzhuling. Nematode faunal analysis revealed that soil food web at Hailun was successionaly more mature or structured, and the environment little disturbed, while at Harbin and Gongzhuling, the soil food web was degraded with stressed environment. The environmental variables relevant in explaining the patterns of nematode distribution and diversity in phaeozem agroecosystems, using canonical correspondence analysis (CCA), were the mean annual temperature, total nitrogen, electrical conductivity, mean annual precipitation, and other soil properties. Among these variables, the mean annual temperature was a relatively important factor, which could explain 29.05% of the variations in nematode composition.

Key Words: agricultural disturbance, canonical correspondence analysis, maize field, nematode faunal analysis, soil biodiversity


INTRODUCTION

It is well recognized that in most terrestrial ecosystems the belowground biota supports a considerably greater diversity of organisms than the aboveground biota (Wardle, 2006); however, our knowledge of the diversity and distribution patterns of soil species and their influence on ecosystem processes is inadequate, partially owing to the high species richness and complexity of belowground ecosystems (Brussaard et al., 1997; Wall and Virginia, 1999; Wardle, 2006). In the search for ways to measure the sustainability of agroecosystems, agricultural soils are of particular practical interest because they underpin the nutrition of humankind. However, the frequent disturbance increases the difficulty of our ability to assess the biodiversity in agricultural soils (Ritz and Trudgill, 1999).

Phaeozem in Northeast China is one of the three zonal phaeozem areas in the world (Wei et al., 2008), distributed in the Songliao Plain and centered in Heilongjiang Province and Jilin Province of China. The high organic matter content and large continuous farmland distribution make it an important area for food production. Long-term overcultivation and improper management in this area have significantly changed the properties of phaeozem soils (Guo and Zhou, 2006). Recent studies re-
ported the changes of soil organic carbon, soil organic phosphorus, and variation of soil properties in the phaeozem region of Northeast China (Yang et al., 2004; Yu et al., 2005; Zhuang, 2007). However, little attention has been paid to the diversity of soil fauna in the phaeozem region, which is one of the important factors influencing the sustainability of agroecosystems.

Nematodes are the most numerous components of the mesofauna in agricultural soils. Some are important as pests of crops and others are involved in decomposition, mineralization, and nutrient cycling (Boag and Yeates, 1998; Yeates and Bongers, 1999). As awareness of the diversity and ecological significance of nematodes has increased, they have increasingly been used as indicators in the areas of biodiversity and sustainability (Bongers and Ferris, 1999; Neher, 2001; Yeates, 2003; Liang et al., 2007; Li et al., 2008). Increasing interest in the biodiversity and the environment, concerns about maintaining the productive capacity of agricultural soils, and the interpretation of a growing knowledge of the contribution of nematodes to soil ecosystem process have resulted in a wider use of ecological indices, such as maturity index (Bongers, 1990), structural index, enrichment index (Ferris et al., 2001; Ferris and Matute, 2003), and so on. These indices facilitate conceptual interpretation and analysis of soil nematode community changes and thus promote bioassessment studies using nematodes as indicators of biodiversity.

This study presents an assessment of diversity and distribution patterns for nematode communities in phaeozem agroecosystems of Northeast China. Our objectives were to evaluate nematode taxonomic diversity and functional diversity in phaeozem agroecosystems along a latitudinal gradient in order to recognize diversity patterns in human modified landscape and to assess the relationship between nematode diversity and soil environmental characteristics.

MATERIALS AND METHODS

Site descriptions

The phaeozem region in Northeast China (43°–50° N, 124°–127° E) covers an area of 5.96 million ha, of which most is located in the middle of Heilongjiang and Jilin Provinces. This region has a semi-humid climate region in a temperate zone with hot-rainy summers and cold-dry winters. The annual precipitation ranges from 500 to 600 mm, with about 90% of the precipitation falling as rain between April and September (Yu et al., 2006). It is a maize-producing area in Northeast China and one of the most important marketable grain bases in China. Maize (Zea mays L.) is planted from May to October every year under conventional tillage. Fertilizers are applied at the average rate of 300 kg N ha⁻¹, 150 kg P ha⁻¹, and 75 kg K ha⁻¹, respectively. Four study sites were selected along a latitudinal gradient from north (Hailun) to south (Gongzhuling). See Zhuang (2007) for details about the main characteristics of the study sites.

Sampling, extraction, and identification of nematodes

Soil samples were collected from north (Hailun) to south (Gongzhuling) down to a depth of 100 cm (subdivided into layers of 0–20, 20–40, 40–60, 60–80, and 80–100 cm) in maize fields in the end of October 2005 after harvest. At each sampling site, four plots (10 m × 10 m for each plot) were randomly selected; four replications were collected in each plot by coring techniques (5 cm diameter). Each replication was composed of 5 soil cores. There were twenty soil samples (i.e., four replications × five depths) per site. After sampling, the samples were stored in individual plastic bags and kept at 4 °C as soon as practical and processed within a week. Sub-samples were air dried for the analysis of soil physicochemical properties. Soil total organic carbon (TOC), total nitrogen, cation exchange capacity (CEC), pH, electrical conductivity (EC) and clay percentage were measured by Zhuang (2007).

A sub-sample (100 g) of each composite sample was taken for nematode extraction by elutriation and sugar-centrifugation (Li et al., 2008), and nematode populations were expressed as number of nematodes per 100 g dry soil. At least 150 nematodes from each sample were identified to genus level.
using an inverted compound microscope. The classification system was based on Siddiqi (1986) and Bongers (1994). Nematode trophic groups were assigned according to known feeding habits or stoma and esophageal morphology (Yeates et al., 1993): i) bacterivores (Ba); ii) fungivores (Fu); iii) plant-parasites (Pl); iv) omnivores (Om); and v) predators (Ca).

Data analysis

Simpson’s evenness index was calculated to determine the effects of sampling site and sampling depth on nematode taxonomic diversity (Magurran, 1988). Nematode generic richness (S) is the total number of genera (Ekschmitt et al., 2001). The effects of sampling sites and soil depths on nematode community structure were assessed via the structure index (SI), enrichment index (EI), and channel index (CI). These indices are indicators for the soil food web structure and condition (indicating functional diversity) (Ferris and Matute, 2003; De Deyn et al., 2004). They were calculated via weighted abundances of nematodes in different functional guilds, taking their position on the colonizer-persister (cp) scale into account (Bongers and Bongers, 1998; Ferris et al., 2001). Nematodes were assigned to colonizer-persister groups along a one to five scale, ranging from enrichment opportunists (cp-1) to taxa which do not tolerate disturbance (cp-5) (Bongers 1990; Bongers and Ferris, 1999).

Nematode abundance was ln(x + 1) transformed prior to statistical analysis. Two-way ANOVA was applied to test the effects of sampling sites and soil depth as main effects and their two-way interaction on nematode abundance and diversity indices. Statistical analyses were performed using SPSS statistical software (SPSS Inc., Chicago, IL). Differences with $P<0.05$ were considered significant.

The relationships between nematode genera and soil environmental variables were analyzed by the Canonical Correspondence Analysis (CCA) using CANOCO software (ter Braak, 1988).

RESULTS

Nematode abundance

The abundance of soil nematodes fluctuated at different sampling sites and soil depths, with the greatest abundance (333 individuals per 100 g dry soil) found at 0–20 cm soil layer of Dehui and the lowest abundance (22 individuals per 100 g dry soil) at 80–100 cm soil layer of Harbin (Fig. 1a). Significant effects of sampling sites, soil depths, and the interaction of both were observed in the abundance of total nematodes (Table I).

TABLE I
Two-way ANOVA table of $P$-values on the effects of sampling site and soil depth on soil nematode abundance and diversity

<table>
<thead>
<tr>
<th>Effect</th>
<th>TNEM$^a)$</th>
<th>Taxonomic diversity</th>
<th>Functional diversity$^b)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Genera richness</td>
<td>Evenness</td>
</tr>
<tr>
<td>Site</td>
<td>&lt; 0.01</td>
<td>0.013</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Depth</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>ns$^c)$</td>
</tr>
<tr>
<td>Site x Depth</td>
<td>&lt; 0.01</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

$^a)$The abundance of total nematodes; $^b)$EI = enrichment index; SI = structural index; CI = channel index; $^c)$No significant difference.

Nematode taxonomic diversity

A total of 40 nematode genera were found in the phaeozem agroecosystems from Hailun to Gongzhuling (Table II). Among the identified nematode genera, Anaplectus, Eucephalobus, and Heterocephalobus at Hailun site, Acrobeles and Prorhabditis at Harbin site, and Acrobeloides at all sampling sites were dominant among the general opportunist bacterivores (Ba1 and Ba2). Ditylenchus at Harbin and Aphe-
Fig. 1  Distribution of nematode abundance (a), generic richness (b), evenness (c), and channel index (d) in the 0–100 cm soil profile at the four sampling sites in Northeast China (Error bars indicate standard error).

lenchus at all sampling sites were dominant fungivores. *Heterodera* at Hailun and *Scutylrenchus* at all sampling sites were prevalent plant feeders with relative abundance greater than 5%.

Generic richness in different sampling sites decreased with the increase of soil depth (Fig. 1b) and varied among sampling sites in 0–100 cm soil profile, with the smallest value (i.e., 5 genera) observed at the depth of 80–100 cm at Hailun, Harbin, and Gongzhuling, and the greatest value (i.e., 14 genera) observed at the depth of 0–20 cm at Dehui. Significant sampling site (*P* < 0.05) and depth effects (*P* < 0.01) were observed in the generic richness (Table I).

The values of Simpson’s evenness fluctuated among different sampling sites. Higher values were observed at Hailun and Harbin than at Dehui and Gongzhuling (Fig. 1c). No significant depth effects were found in the values of evenness during the study period.

*Nematode functional diversity*

During the study period, the values of CI were significantly higher at Hailun than at Gongzhuling (*P* < 0.01) (Fig. 1d), and no significant depth effects were observed in the values of CI. Significant sampling site effects were observed in the values of EI and SI (*P* < 0.01), while significant interaction effects of sampling site and soil depth were only found in the values of SI (*P* < 0.05) (Table I). Since the cultivation mainly influenced the plough horizon, the faunal profiles were constructed for each sampling site at 0–40 cm soil layers (Fig. 2). The faunal profile revealed that the food webs at Hailun were successionally mature or structured, and the soil environments were only subjected to low or moderate disturbance, because most plots of Hailun were clustered in quadrat C. Most plots appeared in quadrat D at Harbin and Gongzhuling, indicating stressed disturbance and degraded food web condition at these sampling sites.

*Relationships between nematode genera and environmental variables*

CCA was used to assess the relative importance of environmental variables in explaining the patterns
TABLE II
Relative abundance of nematode genera in the 0–100 cm soil profile at the four sampling sites

<table>
<thead>
<tr>
<th>Functional group&lt;sup&gt;a)&lt;/sup&gt;</th>
<th>Taxa</th>
<th>Sampling site</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hailun</td>
<td>Harbin</td>
</tr>
<tr>
<td>Ba1 Mesorhabditis (Mesh)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.9</td>
<td>0.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Ba1 Protorhabditis (Pro)</td>
<td>1.2</td>
<td>7.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Ba2 Acrobeles (Acr)</td>
<td>0.9</td>
<td>8.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Ba2 Acrobeloides (Acri)</td>
<td>6.1</td>
<td>11.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Ba2 Anaplectus (Ana)</td>
<td>6.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ba2 Cephalobus (Cep)</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ba2 Cercothelus (Cer)</td>
<td>0.0</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Ba2 Chloroplacus (Chi)</td>
<td>1.1</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Ba2 Eucephalobus (Euc)</td>
<td>6.9</td>
<td>1.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Ba2 Eumonomkystera (Eum)</td>
<td>0.6</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Ba2 Heterocephalobus (Het)</td>
<td>11.0</td>
<td>2.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Ba2 Plectus (Ple)</td>
<td>0.0</td>
<td>2.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Ba2 Wilsonema (Wil)</td>
<td>0.0</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Ba3 Prisomatolaimus (Pri)</td>
<td>0.2</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Fu2 Aphelenchoides (Apho)</td>
<td>0.0</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Fu2 Aphelenchus (Aph)</td>
<td>9.5</td>
<td>9.0</td>
<td>10.1</td>
</tr>
<tr>
<td>Fu2 Ditylenchus (Dit)</td>
<td>2.0</td>
<td>5.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Fu4 Tylencholaimus (Tylic)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Pl2 Aglenchus (Agl)</td>
<td>0.0</td>
<td>3.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Pl2 Boledorbus (Bol)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Pl2 Colesnchus (Cos)</td>
<td>0.0</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Pl2 Felchenus (Fil)</td>
<td>1.8</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Pl2 Paratylenchus (Paru)</td>
<td>7.5</td>
<td>13.8</td>
<td>23.8</td>
</tr>
<tr>
<td>Pl2 Tylrenchus (Tylc)</td>
<td>0.9</td>
<td>2.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Pl3 Creconemoides (Cri)</td>
<td>0.2</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Pl3 Heterodera (Het)</td>
<td>19.8</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Pl3 Helscotylenchus (Hel)</td>
<td>0.0</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Pl3 Paratylenchus (Par)</td>
<td>0.0</td>
<td>0.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Pl3 Scutytlenchus (Scu)</td>
<td>15.3</td>
<td>21.2</td>
<td>29.0</td>
</tr>
<tr>
<td>Pl4 Thomsia (Thor)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Pl5 Longidorus (Lon)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Om4 Coomansus (Coo)</td>
<td>0.4</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Om4 Epidorylaimus (Epi)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Om4 Eudorylaimus (Eud)</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Om4 Microdorylaimus (Mic)</td>
<td>0.5</td>
<td>0.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Om4 Thonus (Tho)</td>
<td>4.5</td>
<td>0.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Om5 Nygolaimoides (Nyg)</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Om5 Paraconchion (Parx)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Om5 Aporcelaimellus (Apo)</td>
<td>0.9</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Ca5 Discolaimus (Dis)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Ca5 Generic Richness</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
</tbody>
</table>

<sup>a)</sup>Functional groups of soil nematodes characterized by feeding habits and life-history characters. Ba = bacterivores; Fu = fungivores; Pl = plant-parasites; Om = omnivores; Ca = predators; numbers following the functional groups indicate the c-p values (Bongers and Bongers, 1998; Ferris et al., 2001).

<sup>b)</sup>Words in parenthesis are abbreviations for nematode genera.

of nematode occurrence in the phaeozem agroecosystems. On the CCA diagram (Fig. 3), Axis 1 is defined by the soil variables: cation exchange capacity (CEC), pH, electrical conductivity (EC), total nitrogen, total organic carbon, clay percentage, and mean annual temperature (MAT); Axis 2 is defined by C/N ratio and mean annual precipitation (MAP). The eigenvalues (lambda) were $X_1 = 0.2650$, $X_2 = 0.1654$. The species–environment correlations were 0.995 for axis 1 and 0.982 for axis 2.
Fig. 2 Nematode faunal analysis in the 0–40 cm soil layer at the four sampling sites of Northeast China.

Fig. 3 Canonical correspondence analysis (CCA) diagram for soil nematode communities in phaeozem agroecosystems. The numbers 11–15, 21–25, 31–35, and 41–45 represent different sampling depths at Hailun, Harbin, Dehui, and Gongzhuling, respectively. Abbreviations on arrows: CEC = cation exchange capacity; EC = electrical conductivity; TN = total nitrogen; TOC = total organic carbon; Clay = clay percentage; MAT = mean annual temperature; MAP = mean annual precipitation; CN = C/N ratio. Abbreviations for genera: Acr = Acrobeles; Acri = Acrobeloides; Agl = Aglenchus; Ana = Anaplectus; Aph = Aphelenchus; Apho = Aphelenchoides; Apo = Aporcelaimellus; Bol = Boleodorus; Cep = Cephalobus; Cer = Cervidellus; Chi = Chiloplacus; Coo = Coomansus; Cos = Coslenchus; Cri = Criconemoides; Dis = Discolaimus; Dit = Ditlenchus; Epi = Epidorylaimus; Euc = Eucephalobus; Eud = Eudorylaimus; Eum = Eumanhystera; Fil = Filenchus; Hed = Heterodera; Hel = Helicotylenchus; Het = Heterocephalobus; Lon = Longidorus; Mesh = Mesorhabditis; Mic = Microdorylaimus; Nyg = Nygolaimoides; Paru = Paratylenchus; Parx = Parunhystera; Ple = Plectus; Pra = Pratylenchus; Pri = Pristionchus; Pro = Protorhabditis; Scu = Scutylenchus; Tho = Thonus; Thor = Thornea; Tyl = Tylenchus; Tylc = Tylencholaimus; Wil = Wilsonema.

Most of nematode genera are widespread, and are positioned in the center of the diagram, such as Acrobeles, Aphelenchus, Scutylenchus, and so on. Nematode genera such as Anaplectus, Heterodera, and Heterocephalobus at Hailun site (sites 11, 12, 13, 14, and 15 located at the upper left-side of the diagram) were positively correlated with total nitrogen, total organic carbon, and clay percentage. At Gongzhuling site, some nematode genera such as Pratylenchus, Pristionchus, Discolaimus, and Criconemoides (sites 41, 42, 43, 44, and 45, located at the upper right-side of the diagram) were positively correlated
NEMATODE DIVERSITY IN PHAEOZEM AGROECOSYSTEMS

with MAP and negatively correlated with soil pH and EC. CEC positively influenced Aglenchus, Fillenchus, and Tylenchus at Harbin site (sites 21, 22, 23, 24, and 25, located at the lower left-side of the diagram), while mean annual temperature and C/N ratio were negatively correlated with nematode genera (such as Plectus, Coslenchus and Aphelenchoidea) present at Dehui site (sites 31, 32, 33, 34, and 35, located at the lower right-side of the diagram). Among the environmental factors, MAT was the most important, which could explain 29.05% of the variations. TN, EC, MAP, CEC, and TOC were relatively more important variables than the clay percentage, soil pH, and C/N in explaining the variations of the nematode community composition in the phaeozem agroecosystems of Northeast China.

DISCUSSION

Agroecosystems are generally characterized by periodic disturbances such as tillage, use of pesticides, and fertilization that impede natural succession. Each of these disturbances has a specific effect but all of them can result in decrease of nematode diversity (Bongers and Bongers, 1998). Phaeozem in Northeast China is characteristic for its high soil organic carbon content and is strongly influenced by human activities and climatic conditions. In this region, the mean annual temperature decreases from south to north, the decomposition intensity of soil microbes may decrease, and the growth periods of maize increase, which can increase the secretion of roots and result in the soil organic matter accumulation in phaeozem (Zhuang, 2007); and different geographic locations have different mean annual temperatures and precipitation, which can apparently influence the nematode diversity and distribution. At Hailun site, the total organic carbon and total nitrogen were higher than in the other sites (Zhuang, 2007), while the abundance of total nematodes and generic richness were significantly lower compared to other sampling sites. The relative low mean annual temperature may contribute to the lower abundance of nematodes and generic richness at Hailun site. In addition, the different reclamation history might be another important factor that affects soil nematode distribution in phaeozem agroecosystems. Since the soil had been cultivated for a longer period in the south (about 150 years in Gongzhuling) than in the north (about 100 years in Hailun), therefore, more soil organic carbon was lost in the south (Yang et al., 2004). Wang et al. (2002) found that soil organic matter decreased with increasing reclamation history in the phaeozem region, and this may influence nematode distribution indirectly. The results showed that the values of CI were higher at Hailun than at Gongzhuling, since the degree of fungal participation in the primary decomposition channels of soil food webs is suggested by the CI (Ferris et al., 2001); the higher values of CI indicated a higher proportion of fungal decomposition occurring at Hailun than at Gongzhuling. The differences in mean annual temperature, precipitation, and reclamation history may help to explain the differences in CI. Other possible reasons might be that when organic matter was degraded and more fibrous, the decomposition was fungal, whereas, it would be more bacterial when organic matter was being replenished by active root growth or new inputs.

In addition, different soil properties were also important limiting factors that affected nematode diversity and distribution. Clay percentage was found to positively influence nematode genera belonging to Ba2 group (such as Eucephalobus, Heterocephalobus) at Hailun site, whereas, EC and soil pH were negatively correlated with nematode genera at Gongzhuling site. In different study sites, the limiting factors that influence nematode genera were different. Freckman and Virginia (1997) studied nematode distribution and diversity in Antarctic soil and found that different nematode taxa were influenced by different factors, Scottnema lindsayae was best related to soil salinity factors (pH and EC), Plectus antarcticus to N and P, and Eudorylaimus antarcticus to moisture and organic C. In three Welsh soils pastures with conventional management, Yeates et al. (1997) found that the proportion of Cephalobidae increased with the clay percentage, where loam > silt > sand, and concluded that in a geographic region, the clay percentage and the proportion of Cephalobidae may be correlated.

Biodiversity, when viewed in relation to the condition of an ecosystem, is not only a matter of a high number of species, but is also concerned with the life strategy of the constituent species. Recently, there is a growing consensus that functional diversity is of crucial importance in determining ecosystem
processes. However, there is still no consistent standard way to quantify functional groups, which is the key to the analyses of function diversity. The structure index and enrichment index based on integration of ‘functional effect’ (trophic group) and ‘response types’ (life strategy classification) may indicate the functional diversity of soil nematodes and accelerate progress in nematode diversity-functioning research (Wu et al., 2002; De Deyn et al., 2004; Liang et al., 2007). The inference of greater structure index at Hailun is that there are more links in the food web, more organism interactions, greater functional redundancy, and potentially, more stability of function.

Nematode faunal profile is a graphic representation of the effect of management practices or other perturbations on the structure and enrichment components of the food web, based on the relative weighted abundance of nematode guilds (Ferris et al., 2001). In this study, the nematode faunal profile showed obvious differences among different sampling sites. The position of all data points in the faunal profiles indicated that the soil food web at Hailun site had fewer disturbances and was more mature than that at Harbin and Gongzhuling, and the different climatic condition, reclamation history, and soil properties may help to explain the discrepancy among the four sampling sites. The obtained results indicated that although taxonomic diversity at Hailun was lower, the faunal analysis showed that the soil food web was relatively mature and soil environment was little disturbed, and therefore, the integration of different methods is promising to discover different aspects of nematodes diversity.

The nematode diversity in phaeozem agroecosystems along a latitudinal gradient offers promising prospects for finding diversity patterns in human modified landscape. However, the effects of geographic location, climate change, and soil properties on the distribution of soil nematodes indicated that the integration of taxonomic diversity and functional diversity would probably prove to be a preferable method to indicate soil disturbance than particular nematode species or ecological indices.

REFERENCES


