Are community structures of soil nematodes different between organic and conventional farming systems in commercial tomato fields?

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Compared with studies conducted in experimental crop fields, those in commercial fields have been very limited to examining how organic (ORG) and conventional (CONV) farming systems differ in their effects on biological and physicochemical characteristics of soils. To evaluate practical effects of ORG systems, a comparison is essential with “practical” CONV systems where organic amendments are also used in addition to chemical fertilizers and pesticides. We compared nematode community structures between the two systems for commercial tomato production in greenhouses located in northern Japan in 2005 and 2006. We examined if the farming system was still influential even when differences in soil texture, study plot locations and growing seasons among the plots were considered. The density of the predator-omnivore group, with *Dorylaimida* as the dominant taxon, and Structure Index were always significantly affected by farming system, and their values were greater in ORG. Redundancy analysis in 2005 revealed that farming system could significantly explain the whole community structure, and determined *Dorylaimida* as an indicator for ORG, while *Diplogasteridae* and *Anguinidae* were indicators for CONV. Although redundancy analysis could not significantly explain community structure with farming system in 2006, *Dorylaimida* and *Diplogasteridae* were still good indicators for the two systems. Individual variables, such as soil texture and bacterial density, were found to have significant effects on the two nematode taxa, although we could not interpret sufficiently the causal relationships. Further studies should include other measurements such as chemical pesticides applied for better interpretation of the differences between these systems. *Nematol. Res.* 39 (2), 63-71 (2009).

Key words : predator-omnivore group, Structure Index.

INTRODUCTION

Recently in Japan organic farming and produce are drawing consumers' attention more and more, with the help of governmental support. For scientific evaluation of an organic farming system, however, it is important to know how the system affects ecosystems in and around crop fields under the system. Several studies have examined if soil microbial and nematode community structure showed some differences between organically and conventionally managed fields (Briar *et al.*, 2007; Bulluck *et al.*, 2002; Ferris *et al.*, 1996; Tsiafouli *et al.*, 2006; Wang *et al.*, 2006). Actually, most of these studies compared effects of organic amendments and chemical fertilizers applied to experimental field plots. In commercial crop fields, however, it is not realistic to expect that no organic amendments will be applied in any type of farm management including a “conventional” one. Accordingly, actual differences should be examined between ORG, organic amendments without

chemical fertilizers and pesticides, and CONV, organic amendments with chemical fertilizers and pesticides. Some studies compared the soil physicochemical and biological characteristics in commercial fields (Liu *et al.*, 2007; Sekiguchi *et al.*, 2008; Taki and Kato, 1998). Nevertheless, only a few studies in different areas of the world (Mulder *et al.*, 2003; Neher, 1999) and none in Japan have examined nematode community structures in commercial crop fields. Nematode community analyses are useful in assessing soil ecosystem status and function, because nematodes are ubiquitous, easy to sample and easy to classify into feeding groups or functional guilds (Ferris and Bongers, 2006; Neher, 2001; Yeates, 2003; Yeates and Bongers, 1999). An additional advantage of using the nematode community is that these animals are likely to be more liable to chemical pesticides (Pen-Mouratov and Steinberger, 2005; Yardirn and Edwards, 1998), than microbiological or physicochemical characteristics of soils. To interpret easily what can be inferred from nematode community structures for soil ecosystem conditions, several indices (weighted means), such as the Maturity Index (Bongers, 1990) and Structure Index (Ferris *et al.*, 2001), have been developed and used in many soil ecological studies (Bongers, <http://www.>

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nem.wur.nl/ UK/Research/Maturity+index/). However, application of these indices is still limited in Japan to a few studies, and they were not conducted in commercial fields but in experimental ones (Okada *et al.*, 2004, Okada and Harada, 2007; Takeda *et al.*, 2009).

It is a challenge to conduct studies in commercial fields for the analysis of causal relationships between biological phenomena and environmental variables. The variables including soil texture, field location and growing season, may not be of scientific interest but may affect analytical results and vary among field plots, thus interpretation and evaluation of the obtained results are sometimes difficult. In our previous studies of microbial characteristics in commercial tomato greenhouses of ORG and CONV farming systems, the location and growing season were different among the greenhouse plots, but these factors were not considered, and sometimes we failed to detect differences between the two systems (Sekiguchi *et al.*, 2008; Urashima *et al.*, 2009). In this study we examined whether or not nematode community structures are influenced by ORG or CONV farming systems in the same plot set, even when taking the effects of soil texture, location and growing sea-

son into consideration.

MATERIALS AND METHODS

Study site, sample collection and nematode analysis:

Twenty-one greenhouses in Yamagata and Fukushima Prefectures in the Tohoku region of Japan were used as field plots in 2005 and 2006 (Table 1). Plots of the normal growing season were surveyed in June, and plots of the late season in August. In each plot at least two planting beds were sampled. The details of the sampling procedure have already been reported elsewhere (Sekiguchi *et al.*, 2008). Briefly, four scoops of soil (15 cm depth) at 4-5 m intervals on each bed were taken to obtain a composite sample from each plot. Soil samples were passed through a 5-mm mesh screen to remove gravel and roots, then gently hand-mixed. A modified Baermann funnel method using trays instead of funnels was employed for the extraction of nematodes from 100 g fresh soil. The details of the extraction procedure, nematode specimen preparation and community analysis have already been reported in Okada *et al.* (2004) and Okada and Harada (2007). Briefly, the extracted nematodes were counted to estimate density per 100 g dry soil, then

Table 1. Farming systems, locations, sampling dates and management summaries of tomato greenhouses used as field plots.¹

System	City or town	Prefecture	Sampling date ²		Main types of organic fertilizer	Synthetic fertilizer use	Chemical pesticide use ³
			2005	2006			
CONV	Yonezasa city	Yamagata	June 22	June 14	Fermented compost	Yes	Yes
CONV	Yonezasa city	Yamagata	June 22	June 14	Cattle feces manure	Yes	No
CONV	Yonezasa city	Yamagata	June 22	June 14	Rapeseed meal, fermented compost	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Cattle feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Pig feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Pig feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Pig feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Pig feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Cattle feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Cattle feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Cattle feces manure with momicara	Yes	Yes
CONV	Shiokawa town	Fukushima	June 21	June 15	Cattle feces manure with momicara	Yes	Yes
CONV	Yonezasa city	Yamagata	June 22	Aug. 1	Commercial fertilizer, rice straw and momicara	Yes	Yes
ORG	Kawanishi town	Yamagata	June 22	June 14	Rice bran, fish meal, fermented compost	No	No
ORG	Aidsuwakamatsu city	Fukushima	June 21	June 15	Food residue compost	No	No
ORG	Aidsuwakamatsu city	Fukushima	June 21	June 15	Fermented compost	No	No
ORG	Yonezasa city	Yamagata	Aug. 11	Aug. 1	Fermented compost	No	No
ORG	Yonezasa city	Yamagata	Aug. 11	Aug. 1	Commercial organic fertilizer	No	No
ORG	Kawanishi town	Yamagata	Aug. 11	Aug. 1	Rice bran, fish meal, fermented compost	No	No
ORG	Yonezasa city	Yamagata	Aug. 11	-	Unknown compost	No	No
ORG	Yonezasa city	Yamagata	Aug. 11	-	Unknown compost	No	No

¹ Fertilizer and pesticide types were unclear for some plots, but organic (ORG) plots certified by organic JAS (Japan Agricultural Standards), used no chemical fertilizer or pesticide. Conventional (CONV) plots used both organic and chemical fertilizers. All plots had been growing tomatoes for at least two years before 2005. Some plots grew other crops such as spinach, leaf vegetables of *Brassica*, before and after tomato cultivation.

² Plots surveyed in June adopted normal season growing, and those in Aug. adopted late growing.

³ Chemical pesticides used in CONV plots were acephate, neonicotinoid, chlorphenapyr, triflumizole, thiophanate-methyl, etc.

fixed in TAF and transferred to anhydrous glycerol prior to being mounted on glass slides for observation. The first 100 individuals encountered were identified to family or generic level to estimate densities of feeding groups as classified mainly according to Okada and Harada (2007) into bacterial feeders (BAC), fungal feeders + facultative root feeders (FFR), predators + omnivores (PROM), obligatory root feeders (ORF), and total density (ALL). Then community indices and diversity indices were calculated (Table 2). Microbial analysis and physicochemical characteristics of the soils:

To determine what types of soil biological and physicochemical characteristics (environmental variables) were affecting nematode community structures, the following measurements and analyses were conducted. To estimate bacterial (Bac, including actinomycetes) and fungal (Fun) densities, a dilution plating technique (PL) was used to determine the number of colony forming units (CFU) per 1 g dry soil. Detailed methodology is described in Sekiguchi *et al.* (2008). Soil phospholipid fatty acid measurements are also commonly used as microbial indicators (Frostegård *et al.*, 1993; Bossio *et al.*, 1998). In this study, molar percentages of the fatty acid of gram negative (PLgn) and positive bacteria (PLgp), actinomycetes (PLac) and fungi (PLfu), together with the total amount of the fatty acid (PLFA, mg/1,000 kg dry soil), were also used as microbial variables. The PLFAs were analyzed in duplicate using 10 g (wet wt) of soil according to the one-phase extraction method of Arao *et al.* (1998). Lipid extracts were evaporated to dryness under nitrogen, dissolved in 100 µl of chloroform and applied to silica Sep-Pak™ columns. The column was eluted with 10 ml chloroform, 10 ml acetone and 6 ml methanol in turn. Each column elutant was considered to correspond to the neutral lipid, glycolipid and phospholipid fractions, respectively. Fatty acid methyl esters were prepared from the phospholipid fraction by methanolysis

using 3% HCl-methanol. GC-MS measurements were conducted on a QP-5000 (Shimadzu Corp.). The physicochemical characteristics of the soils have already been reported in Sekiguchi *et al.* (2008).

Statistical analysis:

First, to examine if farming system (ORG or not) affected nematode density and community indices, a GLM (generalized linear model) procedure and *F*-test were conducted for log-transformed feeding-group densities, community indices and diversity indices. In the procedure, standardized ratios of sand ("sand") and silt ("silt") of soils, and binary data of location (Fukushima or Yamagata Prefecture, "location") and growing season (normal or late, "season") were also used as explanatory variables for nematode characteristics, to determine if the farming system (binary data: ORG or not) still had significant effects independent of these variables. The same analysis was conducted for Bac because it was found to significantly affect some nematode taxa as revealed by the following analysis. Second, RDA (redundancy analysis) was conducted using log-transformed densities of nematode taxa (family or genus) which occurred in four or more plots, to examine if farming system (ORG or not) can explain the whole nematode community structure. Nematodes of the order Dorylaimida are usually not abundant in annual crop fields, but are important indicators of soil ecosystem disturbance (Bongers, 1990), thus we treated all their taxa together as "Dorylaimida" in this study. In the analysis, system was used as a single explanatory variable, while sand, silt, location, and season were designated as co-variables to remove their effects on nematodes. Third, when the system failed to significantly explain the whole nematode community structure, stepwise multiple-regression was conducted for each of the nematode taxa possibly representing ORG or CONV, with system, sand, silt, location, and season as explanatory variables. Finally, to determine specific environmental variables

Table 2. Nematode community indices and diversity indices used.

	Index	Objective of assessment	Unit of groupings used ¹
MI	Maturity Index (Bongers, 1990)	Disturbance in general	Groups of free living taxa based on cp scores
MI2-5	Maturity Index 2-5 (Bongers and Korthals, 1993)	Long-term disturbance in general	Groups of free living taxa without cp 1
MI	Combined maturity index (Yeates, 1994)	Disturbance in general	Groups of free living and plant parasitic taxa
MI2-5	Combined maturity index 2-5 (Yeates, 1994)	Long-term disturbance in general	Groups of free living and plant parasitic taxa without cp1
CI	Channel Index (Ferris <i>et al.</i> , 2001)	Biomass ratio of fungi to bacteria	Functional guilds (BAC1 and FFR2)
EI	Enrichment Index (Ferris <i>et al.</i> , 2001)	Soil enrichment or fertility	Functional guilds (BAC1, 2 and FFR2)
SI	Structure Index (Ferris <i>et al.</i> , 2001)	Food web development	Functional guilds without BAC1 and ORF2-5
H'	Shannon-Wiener's index	Diversity	Every taxon
	Inverse of Simpson's index	Diversity	Every taxon
S	Species richness (number of taxa found)	Diversity	Every taxon

¹ For cp scores and functional guild abbreviations, see Table 3.

which affected significantly the selected nematode taxa, stepwise multiple-regression was again conducted, with the following physicochemical and microbial characteristics of soils as explanatory variables, together with sand, silt, location, and season, after standardization: bulk density (BD), pH, phosphate absorption coefficient (PAC), CEC (me/100 g), amounts (mg/100 g) of CaO, K₂O, MgO, available phosphorus (P), NO₃-N (NO₃), and NH₄-N (NH₄), ratios of total carbon (T-C) and nitrogen (T-N), and bacterial (Bac) and fungal (Fun) CFU, PLgn, PLgp, PLac, PLfu, and PLFA. The GLM procedure, and *F*-test were conducted by the statistical package “R” (R Development Core Team, 2005), RDA by CANOCO™ Version 4.5 (Microcomputer Power, NY, USA), and multiple regression by JMP™ Version 5 (SAS Institute Japan).

RESULTS

In the field plots, 27 nematode taxa were found (Table 3). Among feeding groups, PROM was always significantly

affected by farming system ($P < 0.05$), and was greater in ORG than in CONV (Table 4). Conversely although not significant, ORF density was greater in CONV. Among the community indices examined, Structure Index (SI) was always significantly affected by farming system ($P < 0.05$), and was greater in ORG. Maturity Index (MI) and its relative indices were generally greater in ORG, but differences were not always significant. RDA showed that farming system could significantly ($P < 0.05$) explain whole community structure in 2005 (Fig. 1), and the density of Dorylaimida was significantly greater in ORG, while Diplogasteridae and Anguinidae were greater in CONV (Table 5). In 2006, farming system failed to explain significantly ($P > 0.05$) the whole structure, according to RDA (graph not shown). However, multiple regression models for individual nematodes predicted that Dorylaimida, Diplogasteridae and Anguinidae were in line with the results in 2005, although the model for Anguinidae was not significant ($P > 0.05$, Table 5). Another multiple regression model suggested that

Table 3. Nematode taxa found in the study. The classification of feeding groups and cp scores were according to Yeates *et al.* (1993), Bongers and Bongers (1998), Bongers (1990) and Okada and Harada (2007).

Feeding group	Taxon	Family	Cp score
BAC (Bacterial feeder)	Diplogasteridae	Diplogasteridae	1
	<i>Diploscapter</i>	Diploscapteridae	1
	<i>Eumonhystera</i>	Monhystreidae	1
	Panagrolaimidae	Panagrolaimidae	1
	Rhabditidae	Rhabditidae	1
	<i>Acrobeloides</i>	Cephalobidae	2
	<i>Drilocephalobus</i>	Osstellidae	2
	<i>Plectus</i>	Plectidae	2
	<i>Cylindrolaimus</i>	Diplopeltidae	3
	<i>Prismatolaimus</i>	Prismatolaimidae	3
	<i>Alaimus</i>	Alaimidae	4
FFR (Fungal feeder+ Facultative root feeder)	Anguinidae	Anguinidae	2
	<i>Aphelenchus</i>	Aphelenchidae	2
	<i>Aphelenchoides</i>	Aphelenchoididae	2
	<i>Filenchus</i>	Tylenchidae	2
	<i>Boleodorus</i>	Tylenchidae	2
PROM (Predators+Omnivores)	<i>Achromadora</i>	Achromadoridae	3
	<i>Coomansus</i>	Mononchidae	4
	<i>Mylonchulus</i>	Mononchidae	4
	Qudsianematinae	Qudsianematidae	4
	Nygolaimidae	Nygolaimidae	5
	Aporcelaiminae	Aporcelaimidae	5
	Laimydorinae	Thornenematidae	5
	<i>Opisthodorylaimus</i>	Thornenematidae	5
ORF (Obligatory root feeder)	<i>Heterodera</i>	Heteroderidae	3
	<i>Meloidogyne</i>	Meloidogynidae	3
	<i>Pratylenchus</i>	Pratylenchidae	3

Table 4. Effects¹ of farming system (ORG and CONV) on density, community indices and diversity indices of nematodes, and microbial characteristics.

		2005		2006	
		ORG	CONV	ORG	CONV
Nematode density ² (/100g dry soil)	ALL	6338.3	4611.4 ns	4966.7	5081.4 ns
	BAC	3148.6	3004.4 ns	3111.7	3023.2 ns
	FFR	1451.9	943.3 ns	1019.3	1220.6 ns
	PROM	233.3	2.2 *	93.2	4.4 *
	ORF	1.5	37.3 ns	4.7	14.9 ns
Nematode index	MI	2.03	1.55 *	1.76	1.55 ns
	MI2-5	2.48	2.08 *	2.32	2.07 ns
	MI	2.05	1.62 ns	1.78	1.67 ns
	MI2-5	2.49	2.16 ns	2.34	2.19 ns
	CI	27.16	18.22 ns	17.46	19.90 ns
	EI	70.78	79.30 ns	78.18	78.86 ns
	SI	39.62	10.44 *	30.69	10.84 *
	H'	2.23	2.59 ns	2.22	2.44 ns
	S	7.63	9.46 ns	8.17	9.00 ns
		4.09	5.69 ns	3.89	4.78 ns
Microbial characteristics (CFU/g dry soil)	Bac	4.6E+08	3.6E+08 *	1.6E+08	1.1E+08 ns

¹ Values with * indicate farming system was significant in GLM-setpAIC and *F*-test ($P < 0.05$) procedures with farming system, sand, silt, location and season as explanatory variables.

² Log-transformed to improve inequality of variances.

Table 5. Effects of farming system on the densities of the selected nematode taxa

		Effects of system in regression model, 2006 ²	
Coordinates for t-value biplot in RDA, 2005 ¹		Coefficient	<i>P</i>
System	0.3853	-	-
Dorylaimida	0.2428	positive	0.0145
Diplogasteridae	-0.2589	negative	0.0479
Anguinidae	-0.2193	negative	0.1648

¹ Nematode taxon with smaller absolute value than 0.3853 is significantly predicted by system.

² Regression models included system, sand, silt, location and growing season as explanatory variables.

Table 6. Regression models for the selected taxa representing farming systems.

System	Taxon	Year	Regression model ¹	Adjusted R square	<i>P</i>
ORG	Dorylaimida	2005	- 213.6(PLgpb)+51(PLac)+56.4(sand)	0.4553	0.0038
		2006	41.5(sand)	0.2367	0.0201
CONV	Diplogasteridae	2005	- 123(Bac)+100.1(PLgpb)+114.8(NO ₃)-43.3(Ca)+63.1(silt)+4.6(location)-2.5(season)	0.8810	<.0001
		2006	- 30(Bac)+146.4(PLgpb)-144.6(pH)+67.9(P)-33(sand)	0.6062	0.0030

¹ Objectives, log-transformed nematode density /100 g dry soil, were regressed to standardized explanatory variables by using stepwise procedure with selection criteria of $P = 0.25$. For Dorylaimida, 2006, the criteria was $P = 0.20$ because too many ($7 <$) variables were selected at $P = 0.25$. For abbreviations of variables, see text.

Fig. 1. RDA triplot graph of study plots (ORG, black; CONV, white dot), nematode taxa, and farming system (black triangle), 2005, with sand, silt, location and growing season as co-variables. Cumulative % variance of species was 21.1, and the canonical axis was significant ($P = 0.006$). In 2006, the axis was not significant ($P = 0.36$, graph not shown).

one to seven explanatory variables were affecting *Dorylaimida* and *Diplogasteridae* (Table 6). Among the variables, some were always affecting the nematodes in the same direction, e.g., sand for *Dorylaimida* and Bac for *Diplogasteridae*. Bac tended to be greater in ORG than in CONV, although farming system effects were not always significant (Table 4).

DISCUSSION

To evaluate if an organic farming (ORG) system can affect soil biological characteristics, we used nematodes as representatives of the organisms in soil because of their advantages as indicators (they are ubiquitous, sensitive to chemical pesticides, easy to sample and easy to classify into functional guilds, Bongers, 1990; Ferris *et al.*, 2001). Our study revealed that farming system always affected nematode community characteristics, even when soil texture, field plot location and growing season were taken into consideration, as shown by greater predators + omnivores (PROM) density and Structure Index (SI) values in ORG. Maturity Index (MI) and Maturity Index 2-5 (MI2-5) were also greater in ORG, although not significant in 2006. The reduced number of ORG plots (six) may have caused unclear results of the year. Considering that diversity

indices were not greater in ORG, the greater MI and SI values can be attributed to greater PROM density, rather than development of a complex food web. Examination of the whole community structure also showed that farming system significantly affected the structure, and *Dorylaimida*, *Diplogasteridae* and *Anguinidae* represented the two systems in 2005. Although the farming system did not explain community structure significantly in 2006, *Dorylaimida* and *Diplogasteridae* were each affected by the farming system in the year. Multiple regressions showed that both physicochemical and microbial characteristics affected these nematode taxa. Unfortunately, however, only a few of these variables were consistently influential, thus examination of causal relationships should be limited.

Dorylaimida with cp score of 4-5 accounted for as much as 87% (2006) - 99% (2005) of the PROM group, and this taxon could be most responsible for the consistently greater PROM density, MI and its relatives, and SI in ORG. For this taxon, sand always had a significant effect. This is a reasonable result because *Dorylaimida*, relatively large-sized nematodes (average body size is a little over 1 mm, the largest is 12 mm, according to Jairajpuri and Ahmad (1992), tend to predominate in sandy habitats such as sand dunes (Goralczyk, 1998; Wall *et al.*, 2002). Actually, our previous survey revealed that ORG soils contained more sand than conventional farming (CONV, Sekiguchi *et al.*, 2008). In 2005 for *Dorylaimida*, phospholipid fatty acid % of gram positive bacteria (PLgpb) and actinomycetes (PLac) also had a significant effect. To our knowledge, however, no study is available that explains the relationships of gram-positive bacteria and actinomycetes, to the nematode taxon. From the point of CONV system, a possible explanation for the paucity of *Dorylaimida* is the suppression of the nematodes by chemical pesticides, and their residues and degradation products (Moser *et al.*, 2004), together with chemical fertilizers releasing ammonia in soil. Further studies are needed to evaluate their effects. The CONV "indicator", *Diplogasteridae*, was negatively affected by bacterial density (Bac). This is in accordance with the fact that Bac tended to be smaller in CONV. Considering the microbivorous habits of these nematodes, this result was difficult to interpret. A possible explanation was that some antagonistic bacteria suppressing these nematodes were fewer in CONV.

Quite a few studies have reported differences in nematode community structures between managed systems, but most of these studies examined soils in experimental fields, where the system differences can be attributed mainly to those between organic amendments and chemical fertilizers. In order to evaluate practical effects of systems, the nematode communities in commercial fields should be

examined, where organic amendments, chemical fertilizers and chemical pesticides are all used together under the CONV system. Exceptionally, Mulder *et al.* (2003) examined commercial farms in Dutch grasslands whose systems ranged from certified organic to intensive farming with chemical fertilizers and pesticides. They found that nematode community diversity was influenced by soil pH and livestock density. Neher and Olson (1999) compared ORG and CONV commercial farms of annual crops, although crop species were not always the same. They found that Criconeematidae, Heteroderidae, Plectidae, Prismatolaimidae, and Tylencholaimidae had greater densities in ORG than in CONV, but they did not mention the causal factors. Different from our study, they did not find any significant differences in MI, MI, diversity indices and feeding group densities between the system types. Reportedly for the other biological, or physicochemical soil characteristics, some differences between commercial ORG and CONV systems were found. Taki and Kato (1998) found a trend in that T-C, T-N, CEC, water-stable aggregates ratio, water retentivities, plastic limit, soil animal abundance (*e.g.* earthworms), CO₂ emission, enzyme activities, and quinone amount and its diversity were greater, while solid phase ratios were smaller, in ORG than in CONV in Japan, although their statistical analyses were not sufficient. Liu *et al.* (2007) found that soils from organic farms had improved soil chemical factors and higher levels of extractable C and N, higher microbial biomass carbon and nitrogen, and net mineralizable N in the US. In addition, soil microbial respiration was higher in soils from organic than from sustainable or conventional farms, indicating that microbial activity was greater in the organic soils. Similarly, our current and previous (Sekiguchi *et al.*, 2008) studies found that nematode community structures and soil physicochemical characteristics were different between ORG and CONV, even in commercial fields. Some studies found that chemical herbicide and insecticide affected different nematode taxa in different manners (Neher and Olson, 1999; Pen-Mouratov and Steinberger, 2005; Yardirn and Edwards, 1998). As already mentioned, further studies should evaluate these chemical factors, and the soil physicochemical factors excluded in our study but probably related to farming systems, such as soil-aggregate size distribution, for their effects on nematode community structures in comparisons of ORG and CONV.

We believe that the farming systems affected nematodes by establishing different community structures in some aspects between ORG and CONV. However, it was also true that sand and silt contents of soil which were considered not to be directly related to the systems, sometimes

had a significant effect on the community structures. Another drawback of our study was the reduced number of ORG plots, especially in 2006. Thus, further studies should examine more ORG plots, preferably of the same soil type as CONV plots, to elucidate more clearly farming system effects on nematodes.

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