[Short Communication]

Nematode fauna of paddy field flooded all year round

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The rice paddy fields in Asia are being recognized as biodiversity hotspots. We have reported the seasonal dynamics of nematode communities in a conventional type of paddy field (CPF) in Japan, which is flooded only in spring and summer. The CPF nematode fauna included the typical taxa of bacterial feeders (BAC) and algal feeders (ALG) that inhabit the sediment of freshwater ponds or lakes, as well as fungal feeder + facultative root feeder (FFR) and obligatory root feeders (ORF). Here, we report on the nematode fauna of paddy fields flooded all year round (PFF), which were developed to imitate "yatsu" paddy fields located at the bottom of a valley. We examined the fauna at soil depths of 0–50 mm in May, August, and November, 2008. One half or more of the total nematode abundance was concentrated into the 0–15 mm layer. This concentration was enhanced after the physical disturbances of puddling and rice transplanting in June. Nevertheless, the compositions of feeding groups and nematode taxa were stable across the study seasons, and generally identical across soil layers. PFF fauna comprised typical sediment taxa with two dominant BAC, *Paraphanolaimus* (Aphanolaimidae) and *Paraplectonema* (Leptolaimidae) (60–90% of total density), whereas the FFR and ORF taxa were scarce. Not surprisingly, the PFF fauna was quite different from those in the adjacent terrestrial habitat (ATH), which was composed mainly of FFR and ORF taxa. PFF fauna, however, also had some taxa in common with ATH; *e.g.*, BAC of Monhysteridae, *Aphanolaimus*, and *Chronogaster*. Patches of wet peat moss in ATH might be important for the occurrence of these taxa. Nematol. Res. 46(2) 65–70 (2016).

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INTRODUCTION

Despite international initiatives for conserving paddy field biodiversity at the Ramsar Convention in 2008, limited information is available on the nematode fauna of paddy fields (Yokoo and Su, 1966; Ishibashi *et al*., 1983; Liu *et al*., 2008), although nematodes may play important roles in the food chain there as suggested by studies in natural freshwater habitats (Traunspurger *et al*., 1997; Ajah *et al*., 2006). We have already reported on the soil nematode fauna and their seasonal dynamics in conventional paddy fields (CPF) in Japan, which are flooded periodically in the spring and summer for rice cultivation (Okada *et al*., 2011, 2014). We found that CPF have characteristic nematode taxa such as *Chronogaster*, *Hirschmanniella*, *Tobrilus*, and the nematode community profile differed consistently from that in an adjacent upland rice field cultivated with the same rice variety, throughout a year including the drained period. We also found, however, that CPF and an upland field had some common taxa, such as *Filenchus*, *Acrobeloides*, and *Aphelenchoides*, which were likely to reproduce in CPF after drainage in autumn.

In Japan, we also have another type of paddy field called "yatsuda" or "yatsu" paddy field (hereafter YPF), which is located at the bottom of a valley. Because of the water flow from mountains, a YPF is always wet or flooded throughout the year as a valuable wetland for biodiversity conservation, together with the surrounding woodlands and grasslands (Yamamoto and Kusumoto, 2009). Nakazawa (1999) carried out a taxonomic study of the genus *Mononchus* inhabiting YPF, but no other study is available for the nematode fauna of YPF. We expect that the nematode fauna of this type of paddy field would be quite different from that of CPF; however, no report is available for the nematode fauna in YPF.

In our institute, the National Institute for Agro-Environmental Sciences (NIAES), we have developed a series of terraced paddy fields that imitate YPF for biotope studies. These paddy fields are flooded all year round (hereinafter PFF). In this study, we report on the nematode fauna of our PFF, together with that of an adjacent terrestrial habitat (ATH) as a reference site. Although our PFF is an imitation of YPF, we believe our report can provide fundamental information for biodiversity studies in and around YPF.

MATERIALS AND METHODS

Site description and cultivation management:

The study site was located in our institute in Ibaraki Prefecture, in the metropolitan area of Japan (36º01’ N, 140º07’ E, altitude, 25 m). During the years 2006 to 2008, the mean annual temperature and precipitation ranged from 14.2–14.9ºC and 1184–1663 mm, respectively. The site was established in 1989 as a realistic scale model of a Japanese rural area, and was composed of paddy fields, a farm pond, and a surrounding secondary woodland on a loam soil area (Moriyama, 1995). Since then, the paddy fields were kept wet or flooded throughout the years by continuous water flow from the farm pond located above the paddy fields. We examined three of the five terraced paddy fields in this site, each having a trapezoidal shape of 100–170 m^2. We designated the western half of each paddy field as a PFF plot. We also designated three ATH plots of approximately 7–13 m in length and 1.5 m in width each on the edge of the skirt of an artificial bank along the paddy fields. The bank was planted with some Oak trees (*Quercus serrata*), and was covered with natural undergrowth dominated by Japanese pampas grass (*Miscanthus sinensis*), wheatgrass (*Agropyron ciliare* var. *minus*), and fescue (*Festuca arundinacea*). The lower part of the bank, where we took soil samples, had patches of peat moss (*Sphagnum* spp.). The physicochemical and microbial soil properties of the PFF and ATH plots were assessed in August, 2007 (Table 1). The respective pH, electric conductivity, and dissolved oxygen content of the water in the PFF assessed in July, 2013, were 8.6±0.3, 22.8±0.5 (mS/m), 11.8±0.4 (mg/l, means of three plots ± s.e.). We believe that the properties had not changed greatly from those in 2008 when we examined the nematodes, because the rice cultivation scheme and the surrounding environment were not changed.

PFF plots were flooded throughout the year to maintain a water level of about 6 cm with the water flow from a farm pond located above the top paddy field. We have conducted a single cropping of paddy rice (*Oryza sativa*) every year since 1989 in a fixed manner, including no fertilizer or pesticide application. In 2008, we puddled the fields on 3rd June and transplanted rice seedlings of a Japonica variety (“Rikuu 132”) on 12th June, with a spacing of 30 cm × 30 cm.

Soil sampling and nematode analysis:

We took soil samples on 28th May, 26th Aug. and 11th Nov., 2008. We took six soil cores of 50 mm in diameter and height from each of three PFF plots, whereby each core was at least 100 cm distant from one another, and from the edge of the field. Another six cores were taken on each of three ATH plots. We then separated the soil cores into the top (0–15 mm) and lower (15–50 mm) layers because of their possible difference in oxidation level, and composited each layer in a plastic bag to make a representative sample. For nematode extraction, we used 100 or 150 g of fresh soil and conducted double-layer centrifugation (2,000 rpm, 806 × g, 5 min) followed by Baermann tray extraction for 48 h. We counted the extracted nematodes to estimate their density (no. per ml fresh soil), and we identified 100 randomly selected specimens down to the genus or family level, on glass slides under a compound microscope after formalin fixation and mounting in glycerol. We used the number of each nematode taxon among the 100 individuals to estimate the population density of the whole nematode sample. We assigned each identified taxon to a feeding group (Table 2) mainly according to Yeates *et al.* (1993), with some modifications made following Okada and Harada (2007), resulting in five feeding groups: bacterial feeders (BAC), fungal feeder + facultative root feeder (FFR), predators (PRD),

Table 1. Physicochemical and microbial properties[1] of soil.

Plot and layer	Bulk density	pH	CEC (me/100 g)	Truog P (mg/100 g)	K_2O (mg/100 g)	NO_3-N (mg/100 g)	NH_4-N (mg/100 g)	T-N (%)	T-C (%)	Sand (%)	Silt (%)	Clay (%)	Water content (%)	Fungus (CFU × 10^4/ml)	Bacterium (CFU × 10^6/ml)	F/B × 100
Paddy top layer	0.57	6.2	31.2	1.8	48.2	0.4	1.7	0.5	8.6	18.2	77.9	3.9	75.8 ± 1.1	0.4 ± 0.0	5.5 ± 1.0	6.4
Paddy second layer	0.64	6.7	28.8	1.2	45.3	0.2	4.7	0.4	7.2	25.3	71.7	3.0	67.7 ± 2.5	0.3 ± 0.1	1.4 ± 0.2	19.9
Terrestrial top layer	0.70	6.1	27.1	4.4	66.3	1.7	1.5	0.4	10.3	46.5	32.4	21.1	34.9 ± 3.3	21.6 ± 5.3	106.8 ± 25.8	20.2
Terrestrial second layer	0.89	5.9	19.9	3.1	49.0	0.9	1.0	0.3	5.8	52.3	44.9	2.8	29.6 ± 2.8	20.8 ± 3.7	74.2 ± 7.7	28.0

[1]Water content, and fungal and bacterial colony formation unit (CFU) are means ± s.e. across three plots. Other properties were measured for composite soil samples across three plots, collected in Aug., 2007. Values for CEC, Truog P, K_2O, NO_3-N, NH_4-N were for air-dried soil. Microbial assessment was conducted by a dilution plate technique under an arerobic condition using one gram of fresh soil.

omnivores (OMN), obligatory root feeders (ORF), and algal feeders (ALG). Although some ambiguity remains in their feeding habits, we designated *Tobrilus* and *Rhabdolaimus* here as ALG, because they feed on algae and diatoms (Yeates *et al*., 1993; Traunspurger, 1995).

To obtain an insight on how nematode faunae differ among habitat types, soil depth, and study seasons, we conducted a principal component analysis (PCA). A statistical test was not performed because the paddy plots were connected by some water inlets to make them incompletely independent of each other. PCA was conducted using the relative abundance of each taxon averaged across three PFF or ATH plots. For this type of analysis, nonmetric multidimensional scaling (NMDS) is better, because it is applicable for nonparametric data. Nevertheless, we used PCA instead, with arcsine-transformed data of the nematode taxa detected in five or more samples in a total of 12 (two habitat types, two soil depths and three study seasons), because NMDS was too conservative for our data, and most of the plots were distributed linearly (one-dimensionally) on the ordination in a preliminary analysis. We conducted PCA using "R" (R Development Core Team, 2005).

RESULTS AND DISCUSSION

Within the soil depth of 0–50 mm, one half or more numbers of the PFF nematodes were concentrated in the top soil layer of 0–15 mm, with their densities comparable to the corresponding layer of ATH (Table 2). Such a concentration has been indicated by previous studies of CPF fauna (Ishibashi *et al*., 1983; Okada *et al*., 2011) as well as other studies of lake sediment fauna (Eyualem *et al*., 2006). This phenomenon could be attributed to the possibly greater oxygen content near the soil surface (Schiemer, 1978; Matsunaka, 2003). In contrast, within the second soil layer of 15–50 mm, or the 0–50 mm soil sample as a whole, the nematode density was much lower than that in ATH (Table 2; Fig. 1). Considering that some microorganisms such as blue-green algae can supply nitrogen in paddy field soil, and that plant nutrients can be supplied by water flow even when no fertilizer is applied, the lower nematode density in PFF can be attributed, again, to possibly lower oxygen levels in the soil. After puddling and rice seedling transplanting in June, the concentration of nematodes within the 0–15 mm depth was enhanced. In contrast, however, feeding group compositions of PFF fauna were stable across the three study seasons in both soil layers (Table 2; Fig. 2). Compared with ATH fauna, which comprised mainly FFR and ORF, PFF fauna across soil layers was characterized by the predomination of BAC, accounting for 70–80% of the nematodes detected, followed by ALG (7–15%), throughout 0–50 mm. This trend is almost identical to that observed in our preliminary study of PFF fauna in 2007 (Okada, unpubl.). Bacterial domination over fungi in PFF, suggested by smaller F/B × 100 values in PFF than in ATH in both the top and second soil layers (Table 1), explains the BAC-biased feeding group composition. We could not measure algal biomass in this study. Blue-green algae (cyanobacteria) and other algae are, however, known to prevail on the soil surface in paddy fields, and thus could provide a food source for ALG. The predomination of BAC in PFF fauna is still unique even when compared with that in CPF fauna (Okada *et al*., 2011, 2014), because the PFF fauna scarcely contained FFR and ORF. It is probable that the permanent flooding in PFF constrained fungal growth (Nakamura *et al*., 2003; Table 2) and no fertilizer application retarded the rice growth, both of which led to the scarcity of FFR and ORF.

We detected 49 nematode taxa in this study, with 14 taxa occurring only in PFF fauna (Table 2). PCA illustrated that the nematode fauna of the PFF was, again, different from that of ATH at the taxon level, and that there were only small changes of faunal composition across soil layers and study seasons, in spite of physical disturbance by puddling and transplanting in June (Fig. 3). BAC of *Paraphanolaimus* and *Paraplectonema*, and ALG of *Tobrilus* and *Rabdolaimus* were always characteristically present in PFF fauna. Our preliminary study in 2007 showed an almost identical result (Okada, unpubl). In our study of the CPF fauna, we discussed the characteristics of the fauna and conclude that it is a combination of sediment fauna of ponds and lakes such as Monhysteridae, Tobrilidae, Dorylamidae, Thornenematidae, and Rhabdolaimidae, plus other taxa such as Cephalobidae, Tylenchidae, and Pratylenchidae (Okada *et al*., 2011). In PFF, however, the two BAC, *Paraphanolaimus* (Aphanolaimidae) and *Paraplectonema* (Leptolaimidae), occupied as much as 60–90% of the total density across soil layers. This is very unique when compared with the nematode fauna of CPF, where Cephalobidae, Monhysteridae, and Chronogasteridae were the major BAC (Yokoo and Su., 1966; Liu *et al*., 2008; Okada *et al*., 2011, 2014). *Paraphanolaimus* and *Paraplectonema* are sometimes reported as major members of nematode faunae of sediments in ponds and lakes (Biro, 1968). The predominance of the two genera in PFF fauna suggests that the composition of PFF fauna is closer to that in

Table 2 Densities[a] of nematode taxa (no. /100ml) in top (0–15mm) and second soil layers (15–50mm) of paddy field and terrestrial habitat under study.

Taxon	Family	Abbreviation	May				Aug.				Nov.			
			Paddy		Terrestrial		Paddy		Terrestrial		Paddy		Terrestrial	
			Top	Sec.	Top	Sec.	Top	Sec.	Top	Sec.	Top	Sec.	Top	Sec.
Bacterial feeder (BAC)														
Acrobeloides	Cephalobidae	Acrob	0.0	0.0	268.7	232.4	0.0	0.0	295.3	64.4	0.0	0.0	165.6	153.8
Anaplectus	Plectidae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2
Aphanolaimus	Aphanolaimidae	AphaL	0.0	5.0	0.0	0.0	19.9	0.0	0.0	18.5	0.0	0.0	15.3	12.2
Cervidellus	Cephalobidae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	0.0
Chronogaster	Chronogasteridae	Chron	0.0	4.3	11.1	0.0	7.9	1.0	29.7	0.0	0.0	1.6	15.3	0.0
Diprogasteridae	Diprogasteridae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0
Diploscapter	Diploscapteridae	DiploS	0.0	0.0	0.0	13.4	0.0	0.0	34.7	9.3	0.0	0.0	14.3	14.9
Monhysteridae	Monhysteridae	Monhy	22.5	37.8	74.2	54.3	31.6	4.7	149.9	28.6	146.7	14.2	117.1	82.8
Panagrolaimidae	Panagrolaimidae	–	0.0	0.0	0.0	0.0	0.0	0.0	11.6	16.3	0.0	0.0	14.3	0.0
Paraphanolaimus	Aphanolaimidae	PapHa	1929.6	405.8	0.0	0.0	2255.2	89.0	0.0	0.0	3529.2	333.0	0.0	0.0
Paraplectonema	Leptolaimidae	PapLe	108.6	358.0	0.0	0.0	39.7	139.5	0.0	0.0	46.9	99.0	0.0	0.0
Plectus	Plectidae	Plect	0.0	5.8	85.7	51.3	0.0	0.0	145.1	40.7	16.5	0.0	198.2	37.1
Prismatolaimus	Prismatolaimidae	Prism	0.0	0.0	160.1	13.4	0.0	1.0	58.1	37.9	0.0	0.0	139.6	144.3
Pseudoacrobeles	Cephalobidae	Pseuda	0.0	0.0	77.0	20.9	0.0	0.0	126.3	45.2	0.0	0.0	422.3	197.9
Rhabditidae	Rhabditidae	RhabdI	0.0	0.0	19.4	52.2	0.0	0.0	99.0	0.0	0.0	0.0	15.3	144.3
Wilsonema	Plectidae	–	0.0	0.0	9.7	0.0	0.0	0.0	45.6	0.0	0.0	0.0	49.6	0.0
Total			2060.7	816.8	705.9	437.9	2354.4	235.1	995.2	260.9	3739.3	447.7	1196.6	799.3
(%)			78.0	64.8	21.8	11.6	84.7	66.8	29.7	10.2	91.1	69.6	24.4	19.9
Fungal feeder + facultative root feeder (FFR)														
Aphelenchoides	Aphelenchoididae	AphCO	0.0	0.0	217.7	37.3	0.0	0.0	510.2	90.1	0.0	0.0	194.3	201.6
Aphelenchus	Aphelenchidae	AphCU	0.0	0.0	22.2	31.3	0.0	0.0	59.8	41.8	0.0	0.0	63.9	52.0
Belondiridae	Belondiridae	Belon	0.0	0.0	0.0	26.8	0.0	0.0	12.1	54.2	0.0	0.0	15.3	25.4
Diphtherophora	Diphtherophoridae	–	0.0	0.0	0.0	45.3	0.0	0.0	9.9	9.3	0.0	0.0	0.0	52.0
Filenchus [b]	Tylenchidae	Filen	0.0	5.8	1508.7	1568.9	0.0	0.0	1257.5	770.8	8.3	8.7	2486.7	1382.2
Tylencholaimidae	Tylencholaimidae	Tylen	0.0	0.0	31.9	37.3	0.0	0.0	11.6	70.5	0.0	0.0	14.3	0.0
Total			0.0	5.8	1780.4	1747.0	0.0	0.0	1861.0	1036.7	8.3	8.7	2774.5	1713.2
(%)			0.0	0.5	55.0	46.1	0.0	0.0	55.5	40.6	0.2	1.4	56.5	42.6
Algal feeder (ALG)														
Achromadora	Achromadoridae	–	0.0	0.0	32.6	40.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.4
Odontolaimus	Odontolaimidae	–	0.0	0.0	11.5	20.9	0.0	0.0	0.0	9.3	0.0	0.0	0.0	14.9
Rhabdolaimus	Rhabdolaimidae	RhabdO	119.8	202.0	11.1	24.5	238.4	64.2	12.1	9.8	0.0	57.4	68.5	40.3
Tobrilus	Tobrilidae	Tobri	382.9	160.9	0.0	0.0	162.8	29.4	0.0	0.0	356.5	128.1	15.3	0.0
Total			502.7	362.9	55.2	85.6	401.3	93.5	12.1	19.1	356.5	185.5	83.8	80.6
(%)			19.0	28.8	1.7	2.3	14.4	26.6	0.4	0.7	8.7	28.8	1.7	2.0
Predator (PRD)														
Clarkus	Mononchidae	–	0.0	0.0	9.7	0.0	0.0	0.0	0.0	9.3	0.0	0.0	0.0	14.9
Coomansu	Mononchidae	–	0.0	0.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Doronchu	Anatonchidae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0	18.9	0.0
Mononchus	Mononchidae	–	0.0	0.0	0.0	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mylonchulus	Mylonchulidae	–	0.0	0.0	0.0	41.4	0.0	0.0	21.4	47.9	0.0	0.0	0.0	27.1
Nygolaimidae	Nygolaimidae	–	0.0	5.8	11.5	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Prionchulu	Mononchidae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0
Tripyla	Tripylidae	–	0.0	0.0	11.1	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0
Total			0.0	5.8	43.5	54.9	0.0	1.7	31.3	67.1	0.0	0.0	33.3	41.9
(%)			0.0	0.5	1.3	1.4	0.0	0.5	0.9	2.6	0.0	0.0	0.7	1.0
Omnivore (OMN)														
Actinolaimidae	Actinolaimidae	–	32.6	5.0	0.0	0.0	8.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Aporcelaimidae	Aporcelaimidae	Aporc	0.0	0.0	11.1	13.4	0.0	0.0	12.1	18.5	0.0	0.0	18.9	0.0
Campydora	Campydoridae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2
Dorylaimoides	Mydonomidae	–	0.0	0.0	0.0	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quadsianematidae	Quadsianematidae	–	0.0	0.0	0.0	0.0	0.0	0.0	19.8	0.0	0.0	0.0	63.9	0.0
Thornematidae [c]	Thornematidae	Thorn	13.8	50.8	67.7	40.2	15.8	17.4	86.8	34.3	0.0	0.0	62.9	124.2
Total			46.4	55.8	78.8	67.1	23.8	19.1	118.6	52.8	0.0	0.0	145.7	136.4
(%)			1.8	4.4	2.4	1.8	0.9	5.4	3.5	2.1	0.0	0.0	3.0	3.4
Obligatory root feeders (ORF)														
Coslenchus	Tylenchidae	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0
Criconematidae	Criconematidae	Crico	0.0	0.0	9.7	31.3	0.0	0.0	23.1	64.4	0.0	0.0	58.3	173.6
Ecphyadophoridae	Ecphyadophoridae	–	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	12.2
Helicotylenchus	Hoplolaimidae	Helic	0.0	0.0	438.8	932.7	0.0	0.0	228.8	525.0	0.0	0.0	398.1	720.6
Hirschmanniella	Pratylenchidae	–	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Meloidogyne	Meloidogynidae	Meloi	0.0	0.0	68.8	302.9	0.0	0.0	34.0	432.9	0.0	0.0	219.9	292.1
Paratylenchus	Paratylenchidae	Parat	0.0	0.0	32.6	89.7	0.0	0.0	24.1	71.4	0.0	0.0	0.0	12.2
Pratylenchus	Pratylenchidae	–	0.0	0.0	22.9	10.4	0.0	0.0	0.0	6.4	0.0	0.0	0.0	36.6
Trichodorus	Trichodoridae	–	0.0	0.0	0.0	14.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0
Total			0.0	0.0	572.9	1381.1	0.0	1.0	322.1	1119.4	0.0	0.0	676.3	1247.2
(%)			0.0	0.0	17.7	36.5	0.0	0.3	9.6	43.8	0.0	0.0	13.8	31.0
Unknown taxon			30.5	12.8	0.0	13.4	0.0	1.7	9.9	0.0	0.0	1.6	0.0	0.0
(%)			1.2	1.0	0.0	0.4	0.0	0.5	0.3	0.0	0.0	0.2	0.0	0.0
Total density			2640.3	1259.9	3236.6	3786.9	2779.5	352.1	3350.2	2556.1	4104.1	643.5	4910.2	4018.7
(% in density in 0–50mm depth)			47.3	52.7	26.8	73.2	77.2	22.8	36.0	64.0	73.2	26.8	34.4	65.6

[a]Values are means across three plots of either paddy field or terrestrial habitat.

[b]Included Tylenchids with fine stylets and short or long tails.

[c]Based on definition of Bongers (1988).

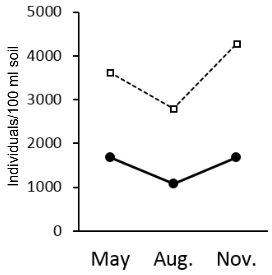

Fig. 1. Nematode density for 0–50 mm depth based on nematode abundance in the top and the second soil layers (Table2). Symbols: circles (black) and squares (white) represent paddy field plots and terrestrial habitat plots, respectively.

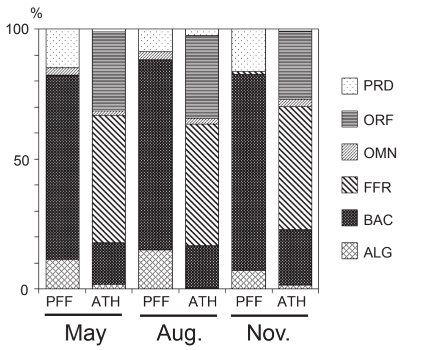

Fig. 2. Feeding group composition for 0–50 mm depth based on nematode abundance of paddy field (PFF) and terrestrial habitat (ATH) plots (Table 2). For abbreviations of feeding groups, see Table 2.

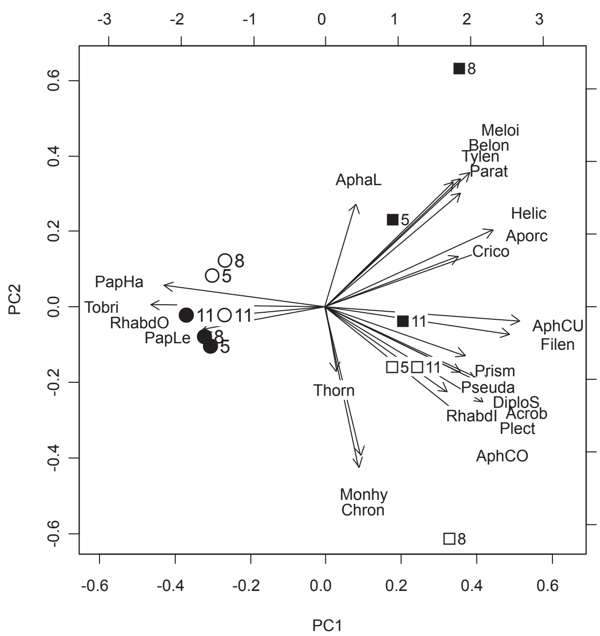

Fig. 3. Results of principal component analysis based on nematode relative abundance. Symbols: open and closed circles represent top and second layer, respectively, of paddy field plots; open and closed squares represent top and second layer, respectively, of adjacent terrestrial habitat plots. Numbers in the ordination indicate sampling months. For abbreviations of taxon names, see Table 2. Taxa detected in five or more samples in a total of 12 were considered.

sediments of stable freshwater habitats, rather than to those of CPF. Temporal disturbance by puddling and transplanting seemed not to affect PFF faunal composition, only if PFF is continuously flooded. Further studies are needed to confirm such a stable composition of nematode fauna in actual YPF, although our PFF is an imitation of YPF (Moriyama, 1995).

Although the nematode fauna of PFF was quite different from that of ATH, we found within the PFF fauna that some taxa are common with ATH fauna: BAC of Monhysteridae, *Aphanolaimus* and *Chronogaster*, and OMN of Thornematidae. The former three taxa are known to occur in both freshwater sediments and wet soil (Eyualem *et al.*, 2006). Peat moss patches in ATH plots suggest that the plots included a wet soil surface, which could harbour these nematode taxa. The definitions of Thornematidae of the order Dorylaimida differ among taxonomists (Bongers, 1988; Jairajpuri and Ahmad, 1992; Vinciguerra, 2006). In this study, we followed Bongers's broader definition of the taxon, which includes more genera, such as *Mesodorylaimus*, *Prodorylaimus*, and *Opisthodorylaimus*, than are defined by other taxonomists. These taxa may have different habitat preferences, *e.g.*, *Mesodorylaimus* may prefer moister, while *Opisthodorylaimus* may prefer drier habitats. Morphological identification of nematode taxa of the order Dorylamida down to the generic or species level is often difficult without pairs of male and female adults. Molecular identification in future studies may reveal habitat preference of each genus or species, to discern whether the nematode taxa really have a broad range of habitat preference.

Different from our study plot in NIAES, YPF could have greater fluctuations in water level and temperature, and could be physically disturbed when rice plants are cultivated. Further studies are needed to examine whether these factors affect nematode fauna of YPF.

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LITERATURE CITED

Ajah, P. O., Georgewill, M.N. and Ajah, M. O. (2006)

The food and feeding habits of five freshwater and brackish-water fish species in Nigeria. African Journal Aquatic Science 31, 313–318.

Biro, K. (1968) The nematodes of Lake Balaton. II. The nematodes of the open water mud in the Keszthely Bay. Annales Instituti Biologici Tihany 35, 100–116.

Bongers, T. (1988) De nematoden van Nederland: een identificatietabel voor de in Nederland aangetroffen zoetwater –en bodembewonende nematoden. Koninklijke Nederlandse Natuurhistorische Vereniging, Utrecht, 408pp.

Eyualem-Abebe, Traunspurger, W. and Michiels, I. (2006) Dynamics of limno-nematodes: abundance, biomass and diversity, In: Freshwater Nematodes: Ecology and Taxonomy (Eyualem-Abebe, Andrássy, I. and Traunspurger, W., eds.),. CABI Publishing, Oxfordshire, 77–93.

Ishibashi, N., Kondo, E. and Ito, S. (1983) Effects of application of certain herbicides on soil nematodes and aquatic invertebrates in rice paddy fields in Japan. Crop Protection 2, 289–304.

Jairajpuri, M. S. and Ahmad, W. (1992) Dorylaimida: Free-Living, Predaceous and Plant-Parasitic Nematodes. Brill, The Netherlands, 458pp.

Liu, M., Chen, X., Qin, J., Wang, D., Griffiths, B. and Hu, F. (2008) A sequential extraction procedure reveals that water management affects soil nematode communities in paddy fields. Applied Soil Ecology 40, 250–259.

Matsunaka, T. (2003) [Fundamentals of Pedology]. Rural Culture Association Japan, Tokyo 389pp. (in Japanese, English title a translation by the authors).

Moriyama, H. (1995) [Biotope combination system with a focus on wildlife conservation in rural area]. Annual report of National Institute for Agro-Environmental Sciences 13, 46–55. (in Japanese, English title a translation by the authors).

Nakamura, A., Tun, C. C., Asakawa, S. and Kimura, M. (2003) Microbial community responsible for the decomposition of rice straw in a paddy field: estimation by phospholipid fatty acid analysis. Biology and Fertility of Soils 38, 288–295.

Nakazawa, K. (1999) Morphological characteristics and ecological survey of three species of the genus *Mononchus* from wet soil in Gunma Prefecture. Japanese Journal of Nematology 29, 16–23. (in Japanese with an English summary)

Okada, H. and Harada, H. (2007) Effects of tillage and fertilizer on nematode communities in a Japanese soybean field. Applied Soil Ecology 35, 582–598.

Okada, H., Niwa, S., Takemoto, S., Komatsuzaki, M. and Hiroki, M. (2011) How different or similar are nematode communities between a paddy and an upland rice fields across a flooding-drainage cycle? Soil Biology and Biochemistry 43, 2142–2151.

Okada, H., Sakai, H., Tokida, T., Usui, Y., Nakamura, H. and Hasegawa, T. (2014) Elevated temperature has stronger effects on the soil food web of a flooded paddy than does CO_2. Soil Biology and Biochemistry 70, 166–175.

R Development Core Team (2005) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Schiemer, F. (1978) Verteilung und Systematik der freilebenden Nematoden des Neusiedlersees. Hydrobiologia 58, 167–194.

Traunspurger, W. (1995) Autecology of *Rhabdolaimus terrestris* De Man –a dominant freshwater nematode in an oligotrophic lake. Nematologica 41, 603–616.

Traunspurger, W., Bergtold, M. and Goedkoop, W. (1997) The effects of nematodes on bacterial activity and abundance in a freshwater sediment. Oecologia 112, 118–122.

Vinciguerra, M. T. (2006) Dorylaimida Part II: Superfamily Dorylaimoidea. In: Freshwater Nematodes: Ecology and Taxonomy (Eyualem, A., Andrássy, I. and Traunspurger, W., eds.),. CABI Publishing, Oxfordshire, 392–467.

Yamamoto, S. and Kusumoto, Y. (2009) Biodiversity and Semi-natural Ecosystems in Paddy Landscape in Japan. Abstract of MARCO symposium, 2009, W4-08. http://www.niaes.affrc.go.jp/marco/marco2009/english/program/workshop/04.html

Yeates, G. W., Bongers, T., de Goede, R. G. M., Freckman, D. W. and Georgieva, S. S. (1993) Feeding habits in soil nematode families and genera –an outline for soil ecologists. Journal of Nematology 25, 315–331.

Yokoo, T. and Su, W. (1966) On the change of the nemic-fauna and the population density in the paddy field before and after the removing of the irrigated water, especially the change of the population density of *Hirschmanniella oryzae*. Agricultural bulletin of Saga University 23, 17–25. (in Japanese with an English summary)

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