Jurnal Ilmu Pertanian Indonesia (JIPI), January 2026
(Indonesian Journal of Agricultural Sciences)
ISSN 0853-4217 EISSN 2443-3462

Vol. 31 (1): 33–43
http://journal.ipb.ac.id/index.php/JIPI
DOI: 10.18343/jipi.31.1.33

Functional Diversity of Nematode on Rice Agroecosystem in Banyumas, Central Java

Mutala'liah*, Lafi Na'imatul Bayyinah, Rama Adi Pratama, Nur Arum Rahmawati, Dwi Mei Widhiana

(Received October 2024/Accepted September 2025)

ABSTRACT

Diversity of ecosystem components in rice agroecosystem is one of the keys to rice growing success. There was still a lack of information regarding the functional diversity of nematodes in the rice agroecosystems, hence the purpose of this study was to investigate the functional diversity of nematodes in rice ecosystems. This study was conducted by collecting samples from rice planting centers in Banyumas: Wangon, Jatilawang, Ajibarang, Rawalo, and Baturraden. Soil samples were collected randomly around rice plants at two places in each subdistrict. A total of 100 g of soil was extracted and isolated using the White-head tray technique. The observed variables were the morphological characteristics and functions of the nematode genus. The Shannon-Weiner diversity index was used to calculate the diversity (H'), evenness (E), and dominance (D) indices. The findings revealed five distinct nematode functions: omnivore-predator (*Eudorylaimus*), omnivore (*Dorylaimus*), microbial feeder and predator (*Diplogaster*), bacterivore (*Cephalobus* and *Rhabditis*), and herbivore (*Hirschmanniella, Meloidogyne, Helicotylenchus*). The most abundant genus was *Eudorylaimus* (32%), followed by *Hirschmanniella* (23%), *Dorylaimus* (17%), *Meloidogyne* 12%, *Helicotylenchus* (8%), *Diplogaster* (4%), and *Rhabditis* and *Cephalobus* (2% each). The H' index ranged from low to moderate, the E index varied from moderate to high, and D indicated that some sites were dominant. In conclusion, the diversity of nematode functions on rice agroecosystems in Banyumas was extensive, although R1 site in Rawalo district should be concerned due to *Meloidogyne* domination.

Keywords: biodiversity, nematodes, paddy, soil

INTRODUCTION

Rice is a vital commodity in Indonesia, serving as a staple diet. Sustainable rice production should be considered because it is linked to national food security. Rice production is impacted by a variety of elements, both biotic and abiotic. Abiotic components include physical elements including soil, water, humidity, temperature, light, rainfall, and wind, whereas biotic components include host plants, pests, natural enemies, and soil bacteria (Jarvis *et al.* 2016). Nematodes are a type of soil microorganism that plays an important part in the agricultural ecosystem. The nematode community in agroecosystems is divided into two types: free-living in soil nematodes and plant parasitic nematodes (PPNs), the majority of which live inside root tissue (Lazarova *et al.* 2021). Nematodes are classified into five trophic groups: bacterivore, fungivore, omnivore, predator, and herbivore or PPNs (Laasli *et al.* 2022).

Climate and soil edaphic variables influence the diversity and abundance of nematodes in agricultural ecosystems (Mondal *et al.* 2023). Soil nematodes in agroecosystems contribute to nutrient degradation, decomposition, carbon management, nutrient dynamics, and serve as biocontrol agents (van den Hoogen *et al.* 2019). The composition of a nematode community in an ecosystem is linked to the nitrogen cycle and decomposition, which are critical factors in soil ecology (Mondal *et al.* 2023). Nematode communities in agroecosystems also play an important function as bioindicators of soil health (Laasli *et al.* 2022). Nematode functional diversity could be utilized to measure habitat health, stability, and biological activity in soil (Liu *et al.* 2015). Research on abundance and diversity in potato plantations reveals a functional diversity of non-parasitic nematodes that enhance plant health, including *Diplogaster, Dorylaimus, Tripyla, Lotonchus,* and *Rhabditis*. *Diplogaster* is a microbial feeder and predator, *Dorylaimus* and Rhabditis are omnivore, *Tripyla* and *Lotonchus* are predatory nematodes (Mutala'liah *et al.* 2023). The nematode population in a rice agroecosystem in Jharkhand, India, included bacterivores, herbivores, fungivores, omnivores, and predators, with bacterivores being the most abundant (Mondal *et al.* 2023). According to nematode diversity in rice agroecosystems in Tebere and Nyangati, Kenya, bacterivores were more dominant than PPNs such as *Aphelenchoides, Longidorus*, and *Helicotylenchus*, as were omnivores such as *Prodorylaimus* (Mokuah *et al.* 2023).

Department of Agrotechnology, Jenderal Soedirman University, Banyumas 53122, Indonesia
* Corresponding Author:
Email: mutalaliah@unsoed.ac.id

Nematode diversity is also influenced by the planting season due to ecological factors that affect soil properties. In spring, free-living nematodes are abundant, whereas PPNs are more numerous in summer. *Diplogaster* was most abundant in the rice agroecosystem in the spring, whereas *Hirschmanniella* and *Meloidogyne* dominated in the summer. Nematode diversity on rice was reported in Jammu and Khasmir, India, comprises of *Acrobelus*, *Aphelenchoides*, *Aphelenchus*, *Cephalobus*, *Rhabdolaimus*, *Criconemoides*, *Cuticularia*, *Diplogaster*, *Diploscapter*, *Discolaimus*, *Ditylenchus*, *Dorylaimellus*, *Dorylaimoides*, *Dorylaimus*, *Eucephalobus*, *Eudorylaimus*, *Globodera*, *Helicotylenchus*, *Heterodera*, *Hexatylenchus*, *Hirschmanniella*, *Hoplolaimus*, *Longidorus*, *Meloidogyne*, *Mesodorylaimus*, *Mesorhabditis*, *Miconchulus*, *Mononchus*, *Mylonchulus*, *Panagrolaimus*, *Paratylenchus*, *Pelodera*, *Pratylenchus*, *Prionchulus*, *Protorhabditis*, *Psilenchus*, *Radopholus*, *Rhabditis*, *Rotylenchus*, *Teratorhabditis*, *Tylencholaimus*, *Tylenchorhynchus*, *Tylenchus*, and *Xiphinema* (Nisa *et al.* 2022). Bacterivores (*Panagrellus* and *Rhabditis*) and herbivores (*Aphelencoides*, *Longidorus*, and *Helicotylenchus*) had the greatest diversity and number of nematodes in Kenya's irrigated rice cropping system (Mokuah *et al.* 2023).

Functional diversity in Indonesia's rice agroecosystem has not been reported. Reports on rice nematodes in Indonesia have only focused on PPNs; however, by researching nematode diversity in rice agroecosystems, it is possible to determine the quality of rice agroecosystems as well as their sustainability. One of the foundations for managing rice agroecosystems is knowledge of the functional variety of nematodes. The presence of non-parasitic nematodes in rice might be used to assess soil health, but a high abundance of PPNs could signal the need for a good control approach to prevent yield losses. The purpose of this study was to investigate the functional diversity and abundance of soil nematodes in the rice agroecosystem, specifically in Banyumas.

METHODS

Materials and Tools

The sampling equipment included a hoe, shovel, root cutters, plastic bags, markers, and raffia rope. For soil extraction and isolation, we used Whitehead tray method with the following components (top−bottom): unscented tissue, nylon gauze, suspension tray, and container tray. A 5 mL counting dish, syringe, microscope (Sinher), Optilab Viewer 4 (Miconos), Syracuse dish, beaker glass, nematode's hook, Petri dish, Bunsen burner, slides, and cover glass were used to see nematodes. The materials in the investigation were soil samples, immersion oil, and sterile water.

Sampling

Sampling was carried out in rice field centers in Banyumas subdistricts, namely: Wangon (W), Jatilawang (J), Ajibarang (A), Rawalo (R), and Baturraden (B). Each subdistrict was sampled at two random sites on the field site. Samples were taken during the vegetative period of rice. The rice fields in the five subdistricts were somewhat flooded. Soil samples were collected around the rhizospheres of rice plants. The amount of sample points collected for each field varied depending on the field area, with the following provisions: (a) field area < 500 m^2: 8−10 sample points; (b) field area < 4,000 m^2: 10−20 sample points; (c) field area < 20,000 m^2: 20−40 sample points (Shurtleff & Averre 2000).

Nematode Extraction–Isolation

Nematode extraction and isolation were performed using the Whitehead-tray method. Soil samples (100 g) were equally distributed on tissue paper at the top of the suspension tray. The container tray was filled with water until the soil was wet and incubated for 24 hours. The nematode suspension in the tray was transferred to beaker glass using a 400-mesh screen (Bell & Watson 2001) and examined directly under a microscope.

Nematode Identification and Population Counting

Nematodes were recognized up to the genus level, and the population was counted using a counting dish under a microscope, picking nematodes and placing them on a slide drizzled with sterile water allowed for identification. Nematodes were viewed using a microscope linked to Opti-Lab Viewer4. Nematode genus identification was based on the University of Nebraska-Lincoln (UNL) online identification key, which may be found at https://nematode.unl.edu/key/nemakey.htm. Stoma, esophagus, tail shape, and other genus-specific characteristics served as morphological markers for nematode identification. Nematode population density for each genus was estimated by multiplying the average number of nematodes obtained from 5 mL of total nematode suspension.

Data Analyses

For further studies, data were examined using studies of Variance (ANOVA) at a 5% error level, as well as the Duncan Multiple Range Test (DMRT) at the same level. The Shannon-Weiner diversity index (H'), evenness index (E), and Simpson's dominance index

(D) were used to assess nematode diversity. Data analysis was performed using *R* statistic version 4.2.1.

RESULTS AND DISCUSSION

Morphological Characters of Soil Nematode Genus

Soil nematodes identified on rice agroecosystems in Banyumas were diverse, comprising eight genera: *Eudorylaimus, Dorylaimus, Cephalobus, Diplogaster, Rhabditis, Hirschmanniella, Helicotylenchus*, and *Meloidogyne*. The many genera discovered had distinct functions, which were then classified into two broad divisions of nematode functions: non-parasitic and plant parasite nematodes. *Eudorylaimus* and *Dorylaimus* are members of the Dorylaimida order of non-parasitic nematodes. *Eudorylaimus* was an omnivore, predatory nematode, whereas *Dorylaimus* was omnivorous. *Cephalobus*, *Rhabditis*, and *Diplogaster* are members of the Rhabditida order, which also includes nonparasitic nematodes. *Cephalobus* sp. and *Rhabditis* are bacterivores, but *Diplogaster* was a microbial feeder and predator. *Hirschmanniella*, *Helicotylenchus*, and *Meloidogyne* are plant-parasitic nematodes from the Tylenchida order.

Dorylaimus had an extended body length ranging from 2 to 9 mm. The genus *Dorylaimus* possessed a powerful and lengthy odontostylet. The female tail was long and filiform, but the male tail was short and circular (Andrassy 2009), exhibited a thick cuticle, obvious longitudinal lines, and offset lips (Cornejo–Condori *et al.* 2021). Dorylaimus' anterior morphology lacked setae, the stoma wall was not sclerotized, and the stylet had no knob or basal flange. The axial stylet was centered and centrally located (Figure 1a). The valve connecting the median and basal esophagus was missing, and the esophageal was basally extended, with an enlarged posterior portion (Figure 1b). The tail of the female was filiform (Figure 1c).

Eudorylaimus had a smooth cuticle, offset lips, and a body size of approximately 0.8−3.5 mm (Ferris 2020). This genus featured a short odontostylet and odontophore (Figure 2a). The esophagus did not have a metacorpus portion (Figure 2b), a short, bluntly rounded tail (Figure 2c). *Eudorylaimus* had a sturdy body that curved at the ventral and resembled an open 'C' following fixing. The tail was conical with a rounded tip and curved to the ventral (Wu *et al.* 2018).

Cephalobus had no setae on its anterior portion. The stoma did not have a stylet or teeth (Figure 3a). A metacorpus was found in the esophagus (Figure 3b), as well as an enlargement in the middle (Figure 3c). This genus' tail was blunt and conical (Figure 3d). It has a stubby and straight body with an average length of 472.86 μm and width of 27.27 μm. The lips were not distinct, the buccal cavity was cylindrical and thin, and the stoma wall was not sclerotized and lacked teeth. The middle of the esophagus grew larger. The cuticle annulation was ineffective. This genus was commonly found in rice agroecosystems and had been documented in China, Japan, Russia, Vietnam, Kenya and Taiwan (Chiu *et al.* 2024; Mokuah *et al.* 2023).

Diplogaster had no setae, and the stoma lacked a stylet. The lips lacked serrations (Figure 4a). The esophagus was enlarged in the center (Figure 4b). The nematode's tail was conical, with a filiform tip (Figure 4c). *Diplogaster* had a huge, powerful stoma, some

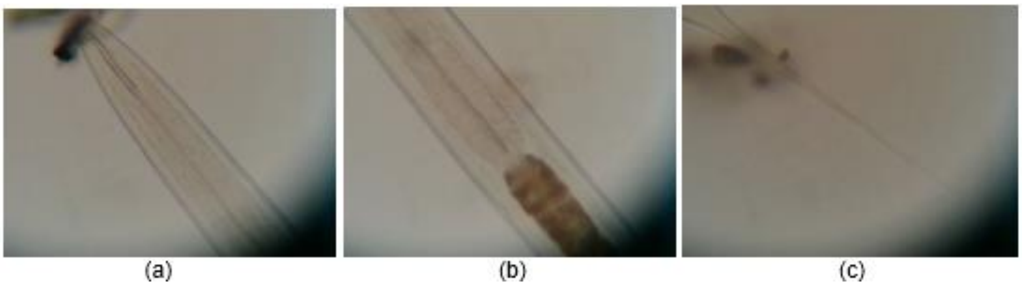


Figure 1 Dorylaimus. (a) Anterior, (b) Esophagus–intestinum, and (c) Posterior.

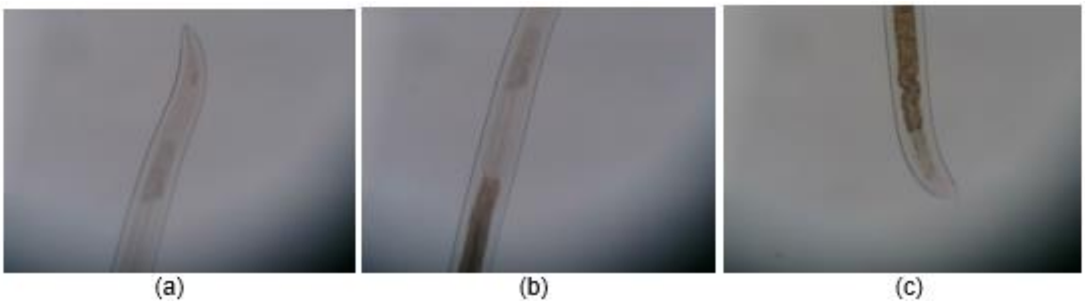


Figure 2 Eudorylaimus. (a) Anterior, (b) Esophagus–intestinum, and (c) Posterior.

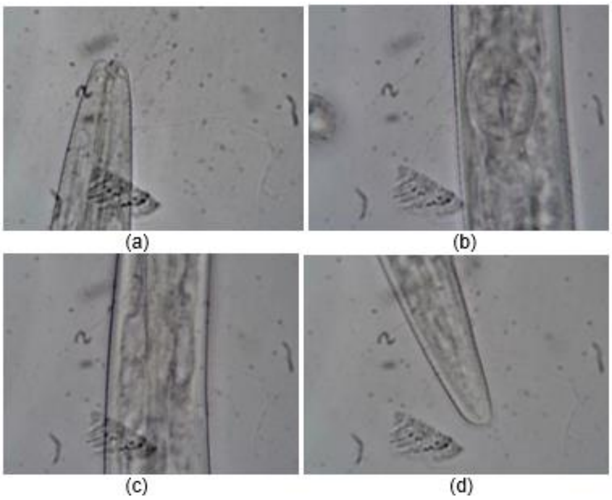


Figure 3 Cephalobus. (a) Anterior, (b) Metacorpus, (c) Esophageal expansion, and (d) Posterior.

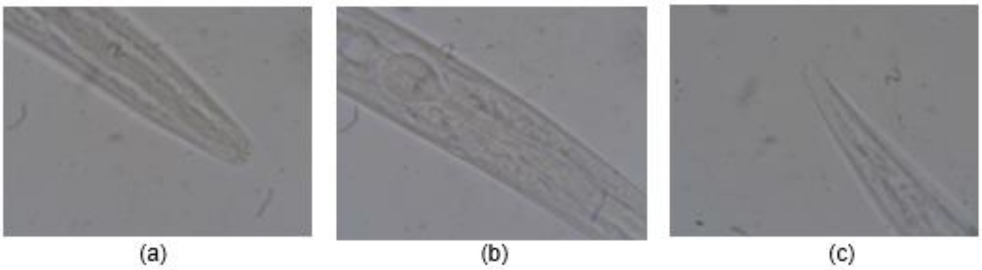


Figure 4 Diplogaster. (a) Anterior, (b) Esophagus, and (c) Posterior.

with teeth and some without. The corpus was sclerotized and contained a metacorpus. The female tail was conical, with or without a filiform tip (Kanzaki *et al.* 2014; Pieterse *et al.* 2017).

Rhabditis was a bacterial-feeding nematode with an extended stoma, no stylet, and stomatal teeth (Figure 5a). The central section of the esophagus enlarged (Figure 5b), and the metacorpus expanded slightly (Figure 5c). The tail resembled a dome (Figure 5d). *Rhabditis*' physical traits were an elongated and slender stoma that was open and cylindrical. The female tails had two shapes: long conical and dome-like (Schulte & Poinar 1991).

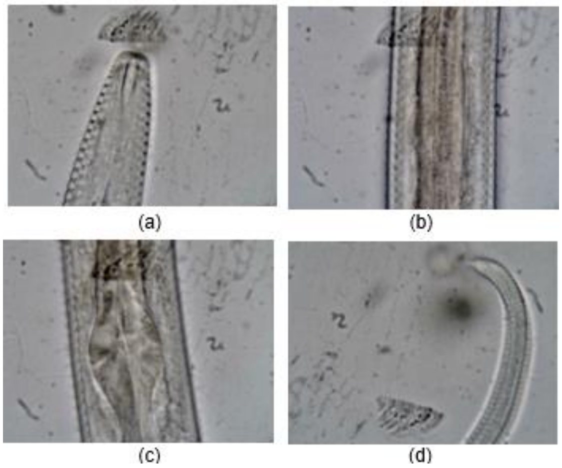
Hirschmanniella's body length ranged from 1−4 mm and was straight and slender. The lips were weak and flat. The stylet structure was sturdy, measuring 15−46 µm in length and with a broad knob. The metacorpus was highly developed, and the esophageal glands extended ventrally into the intestine (Figure 6a). The tail form was identical in male and female, with an extended cone shape and an infrequent mucro near the tail tip (Figure 6b). The male tail features a subterminal bursa structure (Karssen & Hallmann 2022).

Helicotylenchus had a spiral-shaped body in the dead state (Figure 7a). The stylet was sturdy, with clear and rounded knobs (Figure 7b). The tail was asymmetrical, having a projection structure at its tip (Figure 7c). *Helicotylenchus*' body spirals or curves as the nematode dies (Al'as & Gafur 2020). The female vulva was roughly two-thirds the length of the worm body from the anterior end. Many species' tails were asymmetrical, curled dorsally, and had rounded ridges (Subbotin *et al.* 2015).

Meloidogyne displayed sexual dimorphism, with female nematodes having a pear-like form and males being elongated cylindrical. The anterior half of *Meloidogyne* juveniles had offset lips (Figure 8a). The tail of juvenile stage 2 (J2) was pointed and covered in hyaline (Figure 8b). The body of J2 *Meloidogyne* sp. was elongated and cylindrical, tapering towards the posterior. Cuticular annulation was poor. The stylet was small and smooth, with a rounded knob pointed at the back. According to Arun *et al.* 2023 and Nurjayadi *et al.* 2015, the hyaline or translucent tail end measures approximately 18.2 µm and has a gently rounded tip.

Diversity and Abundance of Soil Nematode

The diversity of nematode genus on rice fields in 10 sites in Banyumas comprised of omnivorous-predator, omnivorous, microbial-feeder and predatory, bacterivorous, and herbivorous or plant-parasitic nematodes. Wangon Subdistrict was comprised of the genus *Dorylaimus*, *Diplogaster,* and *Hirschmanniella*. Jatilawang Subdistrict was comprised of *Dorylaimus*, *Eudorylaimus*, and *Hirschmanniella*. *Eudorylaimus* and *Dorylaimus* were the genus found in Ajibarang



(a) (b) (c) (d)

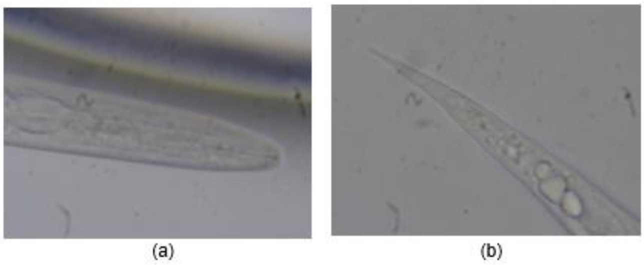
Figure 5 Rhabditis. (a) Anterior, (b) Esophageal expansion, (c) Metacorpus, and (d) Posterior.

(a) (b)

Figure 6 Hirschmanniella. (a) Anterior and (b) Posterior.

(a) (b) (c)

Figure 7 Helicotylenchus. (a) Spiral-body shaped, (b) Anterior, and (c) Posterior.



(a) (b)

Figure 8 Meloidogyne, juvenile stage 2. (a) Anterior and (b) Posterior.

Subdistrict. The following genera were detected in Rawalo Subdistrict: *Dorylaimus*, *Eudorylaimus*, *Rhabditis*, *Diplogaster*, *Cephalobus*, *Hirschmanniella*, *Helicotylenchus*, and *Meloidogyne*. Baturraden Subdistrict was home to *Eudorylaimus*, *Dorylaimus*, *Cephalobus*, *Helicotylenchus*, and *Meloidogyne* (Table 1). The coordinates for the sampling sites were as follows:

W1: 7.49744°S,109.06306°E;
W2: 7.52433°S,109.07330°E;
J1: 7.52510°S,109.08607°E;
J2: 7.53182°S,109.13665°E;
A1: 7.41423°S,109.06675°E;
A2: 7,41044°S,109,07242°E;
R1:7,50551°S,109,15066°E;
R2:7,51589°S,109,16944°E;
B1:7,33542°S,109,23639°E;
B2:7,34133°S,109,21797°E.

The abundance of non-parasitic and plant-parasitic nematode populations varied significantly between

Table 1 Genus diversity of soil nematode on rice agroecosystem in Banyumas

Genus \ Site	W1	W2	J1	J2	A1	A2	R1	R2	B1	B2
Eudorylaimus (omnivore–predator)			✓	✓	✓	✓	✓	✓	✓	✓
Dorylaimus (omnivore)	✓		✓	✓	✓	✓		✓	✓	
Cephalobus (bacterivore)							✓		✓	
Diplogaster (microbial feeder and predator)		✓						✓		
Rhabditis (bacterivore)								✓		
Hirschmanniella (herbivore)	✓	✓	✓					✓		
Helicotylenchus (herbivore)							✓			✓
Meloidogyne (herbivore)							✓			✓

Remarks: A1 (Ajibarang site point 1), A2 (Ajibarang site point 2), B1 (Baturraden site point 1), B2 (Baturraden site point 2), J1 (Jatilawang site point 1), J2 (Jatilawang site point 2), R1 (Rawalo site point 1), R2 (Rawalo site point 2), W1 (Wangon site point 1), W2 (Wangon site point 2).

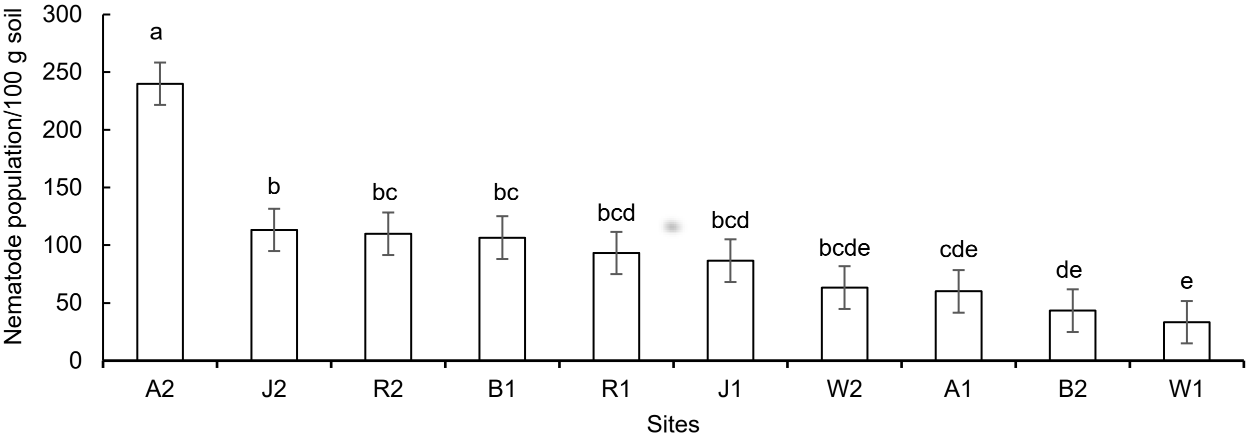


Figure 9 Non–parasitic nematode population on each site. A1 (Ajibarang site point 1), A2 (Ajibarang site point 2), B1 (Baturraden site point 1), B2 (Baturraden site point 2), J1 (Jatilawang site point 1), J2 (Jatilawang site point 2), R1 (Rawalo site point 1), R2 (Rawalo site point 2), W1 (Wangon site point 1), W2 (Wangon site point 2).

sites. The quantity of non-parasitic nematodes at A2 was much higher than at other sites, with an average of 240 nematodes per 100 g soil. W1 had the lowest quantity of non-parasitic nematodes, with an average of 33.33 worms per 100 g soil (Figure 9). R1 had a much higher abundance of plant-parasitic nematodes than others, with 313.33 worms per 100 g of soil. Meanwhile, no plant-parasitic nematodes were detected at the A2, A3, B2, and J5 sites (Figure 10). The high population of plant-parasitic nematodes shows that the soil nematode ecology was imbalanced and capable of causing plant damage. R1 had a higher abundance of plant-parasitic nematodes than non-parasitic nematodes. In contrast, the A2 site contained no plant-parasitic nematodes but the largest population of non-parasitic nematodes. The quantity of non-parasitic nematodes could be utilized to assess soil quality and its ability to sustain plant growth. Pesticide treatments influenced the abundance of nematode populations. Cultivated fields with occasional pesticide application had a lower abundance of beneficial nematode populations and were significantly different from fields without pesticide application (Mutala'liah *et al.* 2023). Chemical pesticides kill both target organisms and beneficial non-target organisms in the soil, such as free-living nematodes. Chemical pesticides may lower the abundance of soil biota and have an impact on the structure of the nematode community in the field due to the poisonous agent. Chemical pesticides had a harmful effect, reducing soil nematode diversity, whereas biopesticides could increase the population of bacterial-feeder nematodes, promoting plant growth (Carrascosa *et al.* 2015).

Diversity study revealed that the B2 location has a greater number of genera than the other sites. H' < 1 indicates little diversity, 1−3 represents medium diversity, while > 3 indicates great diversity. The evenness index is divided into three categories: 0 < E < 0.5, 0.5 < E < 0.75, and 0.75 < E < 1. According to (Tarno *et al.* 2021), a Simpson's dominance index category of 0 < D ≤ 0.5 shows no dominance and 0.5 > D ≥ 1 implies a dominance. The Shannon-Weiner diversity index revealed that W1, W2, J2, A1, A2, and B2 sites were low diversity, whereas J1, R1, R2, and B1 sites were medium diversity. Eight locations had high evenness indexes, including W1, W2, J1, J2, A1, R1, B1, and B2, while A2 and R2 had medium evenness indexes. Simpson's dominance index

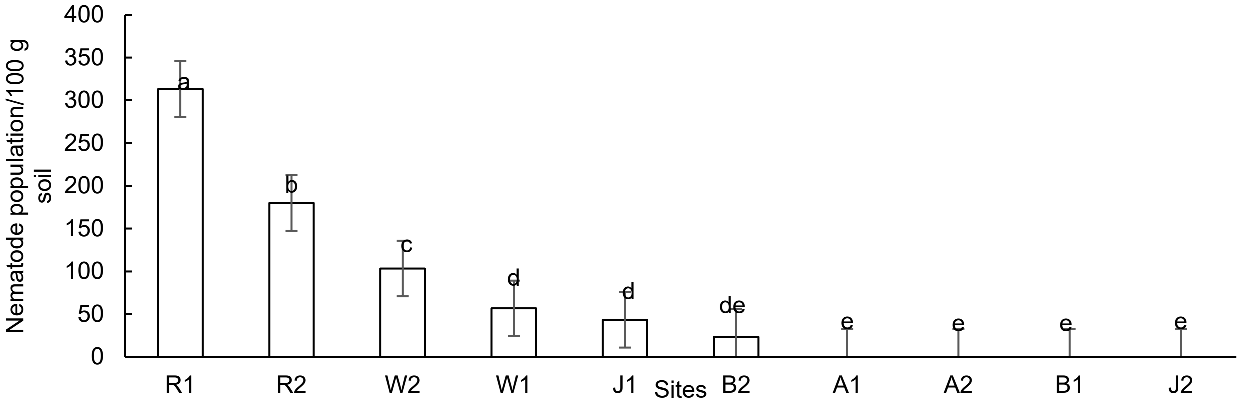


Figure 10 Plant parasitic nematode population on each site. A1 (Ajibarang site point 1), A2 (Ajibarang site point 2), B1 (Baturraden site point 1), B2 (Baturraden site point 2), J1 (Jatilawang site point 1), J2 (Jatilawang site point 2), R1 (Rawalo site point 1), R2 (Rawalo site point 2), W1 (Wangon site point 1), W2 (Wangon site point 2).

Table 2 Mean number of nematode genus population

Site / Genus	Nematode population/100 g soil									
	W1	W2	J1	J2	A1	A2	R1	R2	B1	B2
Eudorylaimus	0	0	50	76.67	26.67	193.33	73.33	43.33	46.67	43.33
Dorylaimus	33.33	0	36.67	36.67	33.33	46.67	0	23.33	43.33	0
Cephalobus	0	0	0	0	0	0	20	0	16.67	0
Diplogaster	0	63.33	0	0	0	0	0	6.67	0	0
Rhabditis	0	0	0	0	0	0	0	36.67	0	0
Hirschmanniella	56.67	103.33	43.33	0	0	0	0	180	0	0
Helicotylenchus	0	0	0	0	0	0	116.67	0	0	13.33
Meloidogyne	0	0	0	0	0	0	196.67	0	0	10

Remarks: A1 (Ajibarang site point 1), A2 (Ajibarang site point 2), B1 (Baturraden site point 1), B2 (Baturraden site point 2), J1 (Jatilawang site point 1), J2 (Jatilawang site point 2), R1 (Rawalo site point 1), R2 (Rawalo site point 2), W1 (Wangon site point 1), W2 (Wangon site point 2).

Table 3 Diversity, evenness, and dominance index

Site	S	H’	E	D
W1	2	0.65	0.95	0.46
W2	2	0.66	0.95	0.47
J1	3	1.09	0.99	0.66
J2	2	0.62	0.91	0.43
A1	2	0.68	0.99	0.49
A2	3	0.49	0.71	0.31
R1	3	1.16	0.84	0.64
R2	4	1.13	0.70	0.57
B1	2	1.01	0.92	0.62
B2	5	0.88	0.81	0.51

Remarks: A1 (Ajibarang site point 1), A2 (Ajibarang site point 2), B1 (Baturraden site point 1), B2 (Baturraden site point 2), J1 (Jatilawang site point 1), J2 (Jatilawang site point 2), R1 (Rawalo site point 1), R2 (Rawalo site point 2), W1 (Wangon site point 1), W2 (Wangon site point 2). S: number of genus; H’: diversity index; E: evenness index; D: dominance index.

revealed the presence of a dominance genus at J1, R1, R2, B1, and B2 sites, but not at W1, W2, J2, A1, or A2 sites (Table 3). The dominant genus at J1 was *Eudorylaimus*, R1 was *Meloidogyne*, R2 was *Hirschmanniella*, and B1 and B2 were *Eudorylaimus* (Table 2).

Eudorylaimus (32%), *Dorylaimus* (17%), *Diplogaster* (4%), *Cephalobus* (2%), and *Rhabditis* were the most common non-parasitic nematode genera. Meanwhile, *Hirschmanniella* (23%), *Meloidogyne* (12%), and *Helicotylenchus* (8%) were the most common plant-parasitic nematode genera (Figure 11). *Eudorylaimus* was an omnivorous predator and free-living nematode. This genus is abundant in soils with high calcium concentrations (Laasli *et al.* 2022). This genus was abundant in Banyumas, as evidenced by its presence in eight of the examined sites. This suggests that the calcium level of most rice fields in Banyumas was high. *Eudorylaimus* was very adaptable to severe environmental circumstances.

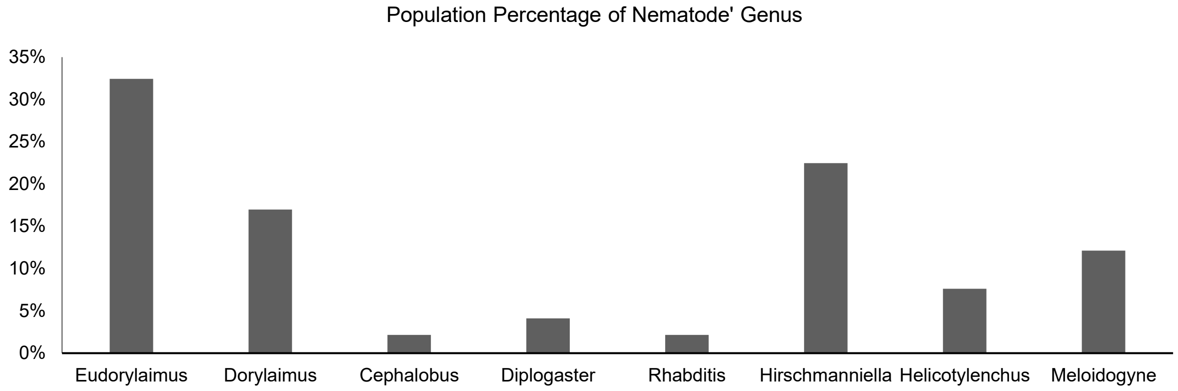


Figure 11 The percentage of genus abundance on rice agroecosystem in Banyumas.

This genus can be found in a variety of soil types, however the soil pH should not be lower than 4 (McSorley 2012). *Dorylaimus* was a free-living, omnivorous nematode (Mirsam *et al.* 2020). Crop diversification and soil pH were identified as factors influencing *Dorylaimus* population abundance (Tarno *et al.* 2021). This genus has been found in coffee (Widowati *et al.* 2014), rubber (Setiawan *et al.* 2019), oil palm and Lembo agroecosystems (Suyadi *et al.* 2021), guava (Sarmah *et al.* 2022), and potato (Sarmah *et al.* 2022). The presence of omnivorous and predatory nematodes in rice agroecosystems was found to be adversely linked with plant-parasitic nematodes (Korobushkin *et al.* 2019). This implied that omnivore nematodes and predators could serve as natural controls for plant-parasitic nematodes. *Eudorylaimus* was an omnivorous predatory nematode capable of preying on *Rotylenchulus reniformis* at a rate of less than 40% (Wang *et al.* 2015). Dorylaimida nematodes had the potential to be excellent predators of plant parasite nematodes and other species. These nematodes feed on other nematodes with their long and powerful odontostylet. These predatory dorylaimids had a diverse host range, preying on a variety of plant parasitic nematodes (Khan & Kim, 2007).

Cephalobus and *Rhabditis* are members of the Rhabditida order, which feeds on bacteria. The presence of bacterivores in the soil accelerates the mineralization of soil organic matter, increases the availability of inorganic nitrogen for plant absorption, and promotes plant root growth. The abundance of bacterivorous nematodes was positively associated with increases in soil nitrogen and indole acetic acid (IAA) content via auxin-dependent pathways (Cheng *et al.* 2016). Gebremikael *et al.* (2016) discovered that the number of bacterial-feeder nematodes was positively connected with the availability of N and P in the soil and their uptake by plants. *Diplogaster* is another Rhabditida genus found in rice agroecosystems, can be both bacterivores and predators (Pieterse *et al.* 2017). Diplogaster was frequently observed in rice and soybean agroecosystems (Musarrat *et al.* 2016). The presence in rice agroecosystems could be utilized to assess ecological balance, which is crucial for soil health. This was demonstrated by its presence in the soil across three growing seasons (Nisa *et al.* 2022). The statistics revealed that *Diplogaster* accounted for only 4% of all site points, was identified exclusively in W2 and R2. This suggests that the rice agroecosystem in W2 and R2 remained balanced.

Hirschmanniella are plant parasitic nematodes that are commonly seen in rice fields. This was consistent with Musarrat *et al.* (2016), who found that it was more widespread on rice fields in Pakistan, followed by *Aphelenchoides*, *Helicotylenchus*, and *Tylenchorhynchus*. *Hirschmanniella oryzae* was one of the world's most damaging *Hirschmanniella* species. They can easily adapt to flooded circumstances, hence this species has been identified as a major concern in flooded rice field ecosystems (Bauters *et al.* 2020). *H. mucronata* was also discovered in Yogyakarta in Cangkringan, while *H. oryzae* was discovered in Imogiri and Banguntapan. Above-ground symptoms of the attack were stunted in plant growth and development and delayed panicle emergence, while the usual root symptom caused by *Hirschmanniella* sp. was necrotic roots that became reddish to brown (Indarti *et al.* 2020). The genus *Hirschmanniella* was favorably linked with soil moisture and fertilizer sensitivity, was shown to be more abundant in fertilized rice fields than in non-fertilized fields (Liu *et al.* 2016). The findings revealed that *Hirschmanniella* sp. were abundant in all four sites (W1, W2, J1, and R2), ranging from 56.67 to 180 nematodes/100 g of soil. This could be a major problem at these sites because *Hirschmanniella* sp. can cause serious damage.

Meloidogyne was discovered to be another herbivorous genus; root-knot nematode, exhibits sexual dimorphism in its adult stage. Juveniles and males had elongated cylindrical or vermiform morphology, while female nematodes were pear-shaped (Cornejo–Condori *et al.* 2021; Khan *et al.* 2023). *M. graminicola* was the most prevalent species detected on rice crops and responsible for severe damage. Above-ground symptoms of an *M. graminicola* attack were reduced plant development and leaf chlorosis. A hook-like gall at the tip of the root was a common symptom (Arun *et al.* 2023).. *Meloidogyne* sp. abundance was quite high in the R1 location, with 196.67 nematodes per 100 g soil, compared to just 10 nematodes in the B2 site. The high abundance at R1 should be considered and handled properly to prevent economic impact. J2 *M. graminicola* concentrations of up to 1500 nematodes per kg of soil at seedling could affect yields by 27−35% (Haque *et al.* 2018; Khan *et al.* 2014). Khan & Ahamad (2020) observed that having as many J2 nematodes as 3851 nematodes per kg of soil might reduce yield losses by 44.6%.

Helicotylenchus was another parasitic nematode that was commonly found in rice production. It could be found in both lowland and upland rice agroecosystems. This genus was most typically found in irrigated and rainfed rice fields (Gnamkoulamba *et al.* 2018). This study also demonstrated that *Helicotylenchus* populations were abundant in both lowland (R1) and upland (B2) fields. Aside from rice, *Helicotylenchus* has been linked to a variety of hosts, including bananas, horticultural crops, ornamentals, and cultivated grasses. It can flourish in a variety of soil conditions, including clay, sandy, and organic matter-rich soils (Crow 2017). According to Sagita *et al.* (2014), *Helicotylenchus* is a plant parasitic nematode that prefers high soil temperatures.

CONCLUSION

Nematodes in Banyumas rice agroecosystems have a wide range of functional roles, including omnivore-predator, omnivore, microbial feeder and predator, bacterivore, and herbivore. *Meloidogyne*, the most abundant plant-parasitic nematode in Rawalo Subdistrict at site 1, requires special attention since it has the potential to reduce crop losses. The functional diversity of nematodes in the rice agroecosystem could serve as an indicator of soil health, particularly in terms of plant development. Following these findings, more research is needed to discover how nematode diversity and abundance effect plant growth and rice production.

ACKNOWLEDGMENTS

The authors thank Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Universitas Jenderal Soedirman for financial support under the Competency Improvement Research Scheme contract number 26.665/UN23.35.5/PT.01/II/2024.

REFERENCES

Al'as N, Gafur A. 2020. Pengelompokan spesies *Helicotylenchus* (Nematoda: Hoplolaimidae) berdasarkan karakter morfologi. *Berkala Sainstek*. 8(4): 106–117. https://doi.org/10.19184/bst.v8i4.17988

Andrassy I. 2009. *Free–living nematodes of Hungary III*. Budapest (HU): Hungarian National History Museum.

Arun A, Shanthi A, Raveendran M, Seenivasan N, Pushpam R, Shandeep G. 2023. An insight into occurrence, biology, and pathogenesis of rice root–knot nematode *Meloidogyne graminicola*. *Biology*. 12(7): 1–18. https://doi.org/10.3390/biology12070987

Bauters L, Kyndt T, De Meyer T, Morreel K, Boerjan W, Lefevere H, Gheysen G. 2020. Chorismate mutase and isochorismatase, two potential effectors of the migratory nematode *Hirschmanniella oryzae*, increase host susceptibility by manipulating secondary metabolite content of rice. *Molecular Plant Pathology*. 21(12): 1634–1646. https://doi.org/10.1111/mpp.13003

Bell NL, Watson RN. 2001. Optimising the Whitehead and Hemming tray method to extract plant parasitic and other nematodes from two soils under pasture. *Nematology*. 3(2): 179–185. https://doi.org/10.1163/156854101750236312

Carrascosa M, Sánchez–Moreno S, Alonso–Prados JL. 2015. Effects of organic and conventional pesticides on plant biomass, nematode diversity and the structure of the soil food web. *Nematology.* 17(1): 11–26. https://doi.org/10.1163/15685411-00002849

Cheng Y, Jiang Y, Wu Y, Valentine TA, Li H. 2016. Soil nitrogen status modifies rice root response to nematode–bacteria interactions in the rhizosphere. *PLoS ONE*. 11(2): 1–19. https://doi.org/10.1371/journal.pone.0148021

Chiu M, Lin T, Lin Z, Lee L, Hsu P, Chen H. 2024. Soil nematode fauna in rice paddy fields from Taiwan based on morphology and DNA barcoding. *Taiwania*. 69(3): 420–434. https://doi.org/10.6165/tai.2024.69.420.

Cornejo–Condori GB, Lima–Medina I, Bravo–Portocarrero RY, Barzola–Tito K, Casa–Coila VH. 2021. Nematodes associated with andean papaya (Carica pubescens l.) in Sandia district, Puno, Peru. *Bioagro*. 33(3): 191–202. https://doi.org/10.51372/bioagro333.5

Crow WT. 2017. Spiral Nematode *Helicotylenchus* spp. (Nematoda: Tylenchida: Hoplolaimidae). In *IFAS Extension University of Florida* (Vol. 2017, Issue

EENY–544). Gainesville (US): IFAS Extension. https://doi.org/10.32473/edis-in973-2017

Ferris H. 2020. *Eudorylaimus*. Nemaplex. http://nemaplex.ucdavis.edu/Taxadata/G722.aspx.

Gebremikael MT, Steel H, Buchan D, Bert W, De Neve S. 2016. Nematodes enhance plant growth and nutrient uptake under C and N–rich conditions. *Scientific Reports.* 6(Sept): 1–10. https://doi.org/10.1038/srep32862

Gnamkoulamba A, Tounou AK, Tchabi A, Kolombia YA, Agboka K, Tchao M, Adjevi AKM, Batawila K. 2018. Occurrence, abundance and distribution of plant–parasitic nematodes associated with rice (*Oryza* spp.) in different rice agroecosystems in Togo. *International Journal of Biological and Chemical Sciences*. 12(2): 618–635. https://doi.org/10.4314/ijbcs.v12i2.1

Haque Z, Khan MR, Ahamad F. 2018. Relative antagonistic potential of some rhizosphere biocontrol agents for the management of rice root–knot nematode, *Meloidogyne graminicola*. *Biological Control*. 126(Aug): 109–116. https://doi.org/10.1016/j.biocontrol.2018.07.018

Indarti S, Soffan A, Andrasmara MMF. 2020. Short communication: First record of *Hirschmanniella mucronata* (Nematoda: Pratylenchidae) in Yogyakarta, Indonesia. *Biodiversitas*. 21(5): 2068–2073. https://doi.org/10.13057/biodiv/d210533

Jarvis DI, Hodgkin T, Brown AHD. 2016. Abiotic and biotic components of agricultural ecosystems. In *Crop Genetic Diversity in the Field and on the Farm*. New Haven (US): Yale University Pr,.

Kanzaki N, Ragsdale EJ, Giblin–Davis RM. 2014. Revision of the paraphyletic genus Koerneria Meyl, 1960 and resurrection of two other genus of Diplogastridae (Nematoda). *ZooKeys*. 30(442): 17–30. https://doi.org/10.3897/zookeys.442.7459

Karssen G, Hallmann JK. 2022. PM 7/94 (2) *Hirschmanniella* spp. *EPPO Bulletin*. 52(2): 314–325. https://doi.org/10.1111/epp.12831

Khan A, Ali MA, Tahir M, Nazeer S, Akram MZ, Azmat MA, Asghar S. 2023. Response of various wheat varieties against root–knot nematodes (*Meloidogyne graminicola*) based on their morphological characters and grain yield. *Sarhad Journal of Agriculture*. 39(4): 944–951. https://doi.org/10.17582/journal.sja/2023/39.4.944.951

Khan MR, Ahamad F. 2020. Incidence of root–knot nematode (*Meloidogyne graminicola*) and resulting crop losses in paddy rice in Northern India. *Plant Disease*. 104(1): 186–193. https://doi.org/10.1094/PDIS-12-18-2154-RE

Khan MR, Haque Z, Kausar N. 2014. Management of the root–knot nematode *Meloidogyne graminicola* infesting rice in the nursery and crop field by integrating seed priming and soil application treatments of pesticides. *Crop Protection*. 63: 15–25. https://doi.org/10.1016/j.cropro.2014.04.024

Khan Z, Kim YH. 2007. A review on the role of predatory soil nematodes in the biological control of plant parasitic nematodes. *Applied Soil Ecology*. 35(2): 370–379. https://doi.org/10.1016/j.apsoil.2006.07.007

Korobushkin DI, Butenko KO, Gongalsky KB, Saifutdinov RA, & Zaitsev AS. 2019. Soil nematode communities in temperate rice–growing systems. *European Journal of Soil Biology.* 93(103099): 1–11. https://doi.org/10.1016/j.ejsobi.2019.103099

Laasli S, Mokrini F, Lahlali R, Wuletaw T, Paulitz T, Dababat A. 2022. Nematodes of food legumes in the Mediterranean Basin. *Diversity*. 14: 1–27. https://doi.org/10.1111/j.1365-2338.1994.tb01395.x

Lazarova S, Coyne D, Rodríguez MG, Peteira B, Ciancio A. 2021. Functional diversity of soil nematodes in relation to the impact of agriculture: A review. *Diversity*. 13(2): 1–22. https://doi.org/10.3390/d13020064

Liu T, Guo R, Ran W, Whalen J, Li H. 2015. Body size is a sensitive trait–based indicator of soil nematode community response to fertilization in rice and wheat agroecosystem. *Soil Biology and Biochemistry*. 88: 275–281. https://doi.org/10.1016/j.soilbio.2015.05.027

Liu T, Whalen JK, Shen Q, Li H. 2016. Increase in soil nematode abundance due to fertilization was consistent across moisture regimes in a paddy rice–upland wheat system. *European Journal of Soil Biology*. 72: 21–26. https://doi.org/10.1016/j.ejsobi.2015.12.001

McSorley R. 2012. Ecology of the dorylaimid omnivore genus Aporcelaimellus, Eudorylaimus, and Mesodorylaimus. *Nematology*. 16(Part 6): 645–663. https://doi.org/10.1163/156854112X651168

Mirsam H, Muis A, Nonci N. 2020. The density and diversity of plant–parasitic nematodes associated with maize rhizosphere in Malakaji highland, South Sulawesi, Indonesia. *Biodiversitas*. 21(6): 2654–2661. https://doi.org/10.13057/biodiv/d210637

Mokuah D, Karuri H, Nyaga JM. 2023. Food web structure of nematode communities in irrigated rice fields. *Heliyon*. 9(e13183): 1–11. https://doi.org/10.1016/j.heliyon.2023.e13183

Mondal S, Ghosh S, Pari A, Bhattacharyya K, Bhowmick AR, Khan MR, Mukherjee A. 2023.

Unveiling the drivers of nematode community structure and function across rice agroecosystem. *Applied Soil Ecology*. 182 (104715): 1–12. https://doi.org/10.1016/j.apsoil.2022.104715

Musarrat AR, Shahina F, Shah AA, Saba R, Feroza K. 2016. Community analysis of plant parasitic and free-living nematodes associated with rice and soybean plantation from Pakistan. *Applied Ecology and Environmental Research*. 14(5): 19–33. https://doi.org/10.15666/aeer/1405_019033

Mutala'liah M, Manan A, Bayyinah LN. 2023. Abundance and diversity of terrestrial free–living nematodes in potato agroecosystem. *Nusantara Bioscience*. 15(1): 129–136. https://doi.org/10.13057/nusbiosci/n150116

Nabilah, Swibawa IG, Suharjo R, Fitriana Y. 2021. Diversity and abundance of nematodes in guava (*Psidium guajava* L.) cultivation in Lampung. *Journal of Tropical Plant Pests and Diseases*. 21(2): 134–143. https://doi.org/10.23960/jhptt.221134-143

Nisa RU, Nisa AU, Hroobi AA, Shah AA, Tantray AY. 2022. Inhibition–indicator nematode genus in rice fields. *Biology*. 11(1572): 1–20. https://doi.org/10.3390/biology11111572

Nurjayadi MY, Munif A, Suastika G. 2015. Identifikasi nematoda puru akar, *Meloidogyne graminicola*, pada tanaman padi di Jawa Barat. *Jurnal Fitopatologi Indonesia*. 11(4): 113–120. https://doi.org/10.14692/jfi.11.4.113

Pieterse A, Malan AP, Ross JL. 2017. Nematodes that associate with terrestrial mollusks as definitive hosts, including *Phasmarhabditis hermaphrodita* (Rhabditida: Rhabditidae) and its development as a biological molluscicide. *Journal of Helminthology*. 91(5): 517–527. https://doi.org/10.1017/S0022149X16000572

Sagita L, Siswanto B, Hairiah K. 2014. Studi keragaman dan kerapatan nematoda pada berbagai sistem penggunaan lahan di SubDas Konto. *Jurnal Tanah dan Sumberdaya Lahan*. 1(1): 51–60. http://jtsl.ub.ac.id.

Sarmah S, Widyastusi R, Supramana S. 2022. Komunitas nematoda pada lahan pertanaman wortel dan hubungannya dengan populasi mikroba tanah. *Jurnal Tanah dan Iklim*. 46(1): 91–102.

Schulte F, Poinar GO. 1991. (Nematoda: Rhabditidae) from the body cavity of beetle larvae in Guatemala. *Revue Nematol*. 14(1): 165–180.

Setiawan DF, Suyadi, Rosfiansyah. 2019. Identifikasi genus Nematoda pada lahan perkebunan karet (*Hevea braziliensis*) di Desa Santan Ulu Kecamatan Marangkayu Kabupaten Kutai Kartanegara. *Jurnal Agroekoteknologi Tropika Lembab*. 1(2): 144–150. https://doi.org/10.35941/jatl.1.2.2019.1981.144-150

Shurtleff M, Averre C. 2000. *Diagnosing Plant Disease Caused by Nematodes*. St. Paul (US): APS Pr.

Subbotin SA, Vovlas N, Yeates GW, Hallmann J, Kiewnick S, Chizhov VN, Manzanilla–López RH, Inserra RN, Castillo P. 2015. Morphological and molecular characterization of *Helicotylenchus pseudorobustus* (Steiner 1914) Golden 1956 and related species (Tylenchida: Hoplolaimidae) with a phylogeny of the genus. *Nematology*. 17(1): 27–52. https://doi.org/10.1163/15685411-00002850

Suyadi, Sila S, Samuel J. 2021. Nematode diversity indices application to determine the soil health status of *Lembo* agroecosystem in West Kutai, East Kalimantan Province, Indonesia. *Biodiversitas.* 22(7): 2861–2869. https://doi.org/10.13057/biodiv/d220737

Tarno H, Marsudi EW, Widjayanti T, Setiawan Y. 2021. Short communication: Nematodes associated with robusta coffee plantations in Malang District, East Java, Indonesia. *Biodiversitas*. 22(8): 3306–3312. https://doi.org/10.13057/biodiv/d220825

van den Hoogen J, Geisen S, Routh D, Ferris H, Traunspurger W, Wardle DA, de Goede RGM, Adams BJ, Ahmad W, Andriuzzi WS, Bardgett RD, Bonkowski M, Campos–Herrera R, Cares JE, Caruso T, de Brito Caixeta L, Chen X, Costa SR, Creamer R, Crowther TW. 2019. Soil nematode abundance and functional group composition at a global scale. *Nature*. 572(7768): 194–198. https://doi.org/10.1038/s41586-019-1418-6

Wang KH, Myers RY, Srivastava A, Sipes BS. 2015. Evaluating the predatory potential of carnivorous nematodes against *Rotylenchulus reniformis* and *Meloidogyne incognita*. *Biological Control*. 88: 54–60. https://doi.org/10.1016/j.biocontrol.2015.04.023

Widowati R, Indarti S, Rahayu BTP. 2014. Sebaran genus nematoda nonparasit tumbuhan pada kopi arabika. *Jurnal Perlindungan Tanaman Indonesia*. 18(1): 24–32.

Wu WJ, Yu L, Xu CL, Wang DW, Xie H. 2018. A new species of the genus Eudorylaimus Andrássy 1959 (Nematoda: Dorylaimida: Qudsianematidae) associated with *Picea crassifolia* in China. *Zootaxa*. 4526(4): 576–588. https://doi.org/10.11646/zootaxa.4526.4.9