Research article

Food web structure of nematode communities in irrigated rice fields

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A B S T R A C T

Nematodes are a key component of the soil food web and they play an important role in the provision of ecosystem services. Rice cultivation in Mwea, Kenya involves the intensive use of fertilizers and pesticides which may affect the complexity of the nematode-based soil food web. This study examined the nematode diversity and food web structure in irrigated rice fields in Nyangati and Tebere in Mwea, Kirinyaga County, Kenya. Nematodes were identified up to the genus level and soil physico-chemical properties were also determined. *Aphelenchoides* and *Longidorus* occurred in significantly greater proportions in Tebere, while in Nyangati there was a high abundance of *Helicotylenchus*. *Aphelenchoides* was positively correlated to soil electrical conductivity. From additive diversity partitioning of genus richness, the α and β components contributed 33.7% and 66.3% of the γ diversity, respectively. For Shannon and Simpson diversity indices, the largest contribution to overall diversity was from α component. Soil food web indices were similar across the two regions. Channel and basal indices were below 30% while Enrichment (EI) and Structure (SI) indices were above 50%. There was no variation in metabolic footprints except for the fungivore footprint which was significantly higher in Tebere. Based on the EI and SI, the soil food web in paddy rice fields in Mwea was structured and enriched with moderate disturbance. Due to the high prevalence of economically damaging parasitic nematodes in the rice fields, appropriate management schemes that enhance specific components of the soil food web and increase the suppressive ability of soil against plant-parasitic nematodes should be implemented.

1. Introduction

In Kenya, rice, the third most important staple crop, is grown in Kirinyaga, Kisumu, Mombasa and Tana River Counties [1,2]. Despite the 12% annual increase in consumption (300,000 tonnes), yield is comparatively low (45,000 to 80,000 tonnes) and the gap is covered through import [2,3]. Yield decreases have been reported despite increased application of nitrogen fertilizers [4]. There are several biotic constraints in Kenyan rice production systems such as viruses, fungi [5–7] and plant-parasitic nematodes (PPN) [8]. In addition to these constraints, irrigated areas that account for 80% of rice production in Kenya, pose additional stress such as high salinity and low fertility. Agricultural intensification affects the soil food web [9] which influences crop productivity [10,11]. A global meta-analysis showed that the application of pesticides and chemical-based fertilizers lowers the structural complexity of the nematode-based soil food web [12]. On the other hand, judicious use of inorganic fertilizers enhances food web structure and increases

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soil suppressiveness against PPN [13]. In some cases, nematode functional guilds provide a greater contribution to the structure of the soil food web compared to other microorganisms as demonstrated by Li et al. [14] in an agricultural field trial.

Nematodes play important ecological roles and they are used as indicators of soil health. Nematode trophic groups in higher levels such as omnivores and predators can suppress PPN that reduce crop yields [15]. There are several PPN that have been reported in rice such as *Helicotylenchus* spp*., Trichodorus* spp., *Xiphinema* spp. (Cote d'Ivoire; [16]), *Aphelenchoides* spp., *Ditylenchus* spp*., Heterodera* spp*., Hirschmanniella* spp*., Meloidogyne* spp. and *Pratylenchus* spp. (recorded in different regions of the world; [17]). Nematode genera that cause significant yield losses in rice include *Aphelenchoides* spp*., Ditylenchus* spp*., Criconemoides* spp*., Heterodera* spp*., Hirschmanniella* spp*., Hoplolaimus* spp*., Meloidogyne* spp*., Paralongidorus* spp*., Pratylenchus* spp. and *Xiphinema* spp. [18]. Certain economically damaging nematodes prefer irrigated areas [19]. For instance, the number of *Hirschmanniella oryzae* [20] and *Meloidogyne graminicola* second-stage juveniles were higher in irrigated areas compared to upland fields in Myanmar [21]. Similarly, in Côte d'Ivoire, the number of *Basiria,* spp. *Filenchus* spp. and *Coslenchus* spp. was greater in high moisture paddy fields [22]. Irrigation in rice cropping systems also affects the nematode-based food web [23] which has a regulatory role against PPN [24].

Disturbance in rice fields alters the food web structure by reducing nematode trophic levels, number of predatory nematodes, enrichment and structure indices [25]. Wang et al. [26] reported alterations in nematode trophic groups and the Plant-Parasitic Index (PPI) due to elevated carbon dioxide in rice paddy fields. Okada et al. [27] revealed that flooding increases the abundance of *k* strategists, lowers the EI and increases the SI. Salinity in irrigated rice fields affects nematode assemblages and trophic groups and reduces the complexity of the food web structure [28]. In order to sustainably control PPN, maintain soil health and related ecosystem functions in Kenyan rice ecosystems, it is important to have information on nematode diversity and its contribution to the soil food web. The aim of this study was to examine the nematode diversity, soil food web indices and metabolic footprints in irrigated rice fields in Mwea, Kenya.

1.1. Methodology

1.1.1. Study area and soil sampling

Irrigated rice fields in Nyangati (0°36'47.4"S 37°21'11.4"E) and Tebere (0°38'10.9"S 37°21'44.0"E) regions of Mwea, Kirinyaga County (Fig. 1) were sampled in April 2022. The soil in the fields is classified as Eutric Nitisols [29]. Annually, the region has two rainy seasons with approximately 930 mm rainfall and average temperature between 14 °C - 31 °C [30]. For this study, fields that were cultivated with monoculture rice for 10–15 years were selected. The sampled fields had the same management practices whereby they had received a basal fertilizer input (NPK; 17:17:17) and ammonium sulfate top dressing after 45 days of transplanting. In addition,
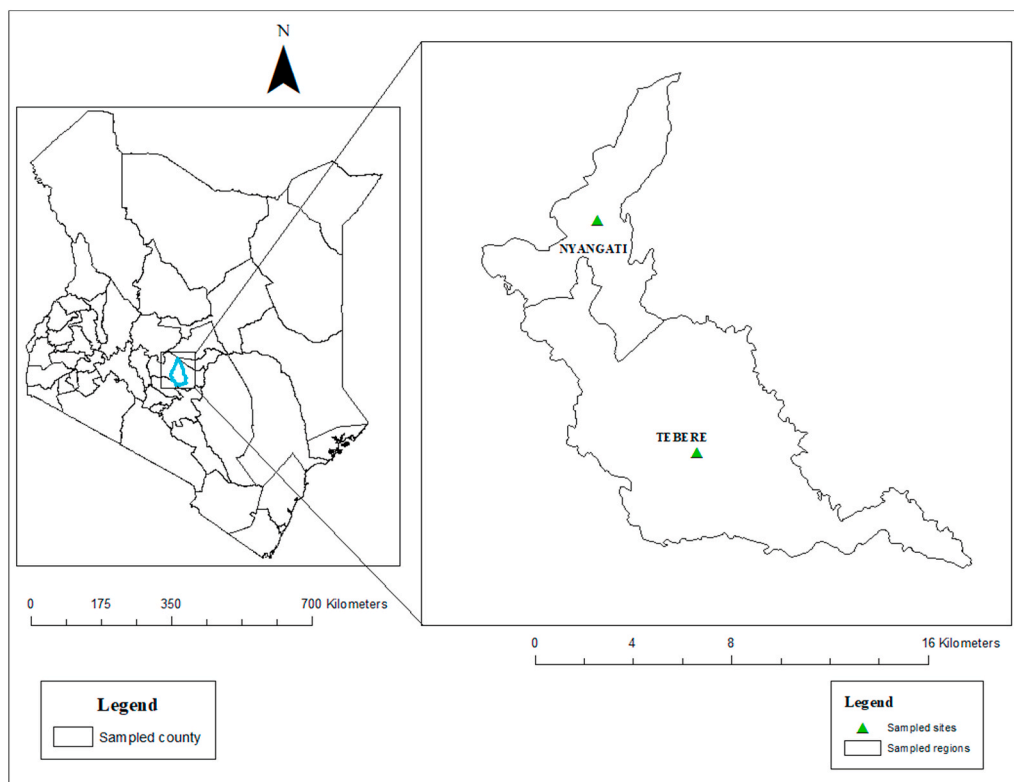

Fig. 1. Study areas at Nyangati and Tebere, in Mwea, Kirinyaga County, Kenya where nematode samples were obtained.

insects were controlled with applications of Oshothion 50EC and Diazol 60EC. Soil samples were collected from fields cultivated with the rice variety Basmati 370 at four months after planting. Thirty fields in Nyangati (15) and Tebere (15) were sampled. Based on the sampling protocol described by Wiesel et al. [31], soil samples from each field were collected from three W shaped "sample walks" at 25 cm depth. From each field one 4 kg composite soil sample was collected for analysis of nematode communities and soil physico-chemical properties.

1.1.2. Nematode analyses

From the composite soil sample, three 250 g sub-samples were used for nematode extraction using the modified Baermann technique [32] for 48 h. Nematodes were fixed using a hot mixture of formaldehyde and glycerin [33]. They were then placed in a counting dish for enumeration. The nematodes were identified to the genus level [34,35] using a compound microscope. Soil physico-chemical properties were assessed at the Kenya Agricultural and Livestock Research Organization, National Agricultural Research Laboratories. The hydrometer technique [36] was used to examine the soil texture while Mn, Mg, Ca, K, Na, P and pH were assessed following the method by Mehlich et al. [37]. The amount of N and C was determined using Kjeldahl digestion method [38] and colorimetric technique [39], respectively. Atomic Absorption Spectrophotometer was used to analyze Zn, Cu and Fe content [37].

1.1.3. Data analysis

From the triplicate samples, the average number of nematodes was used in subsequent analyses. Nematode indices (PPI, maturity index of nematodes belonging to colonizer-persister group 1–5; MI, Maturity index excluding cp1 nematodes; MI 2–5, SI, EI, basal index; BI and channel index; CI) and metabolic footprints were computed using the Nematode Indicators Joint Analysis online program [40]. The MI, MI 2–5, SI, BI and CI provide information on the level of disturbance in the ecosystem and the condition of the soil food wed. On the other hand, metabolic footprints indicate the ecosystem services provided by different nematode trophic groups [41]. Prior to analysis, the Shapiro-Wilk test was used to asses normality of the nematode abundance data which was subsequently $\log(x+1)$ transformed. One-way analysis of variance (ANOVA) with Tukey post hoc test was used to evaluate differences in number of nematode genera, indices and metabolic footprints in Nyangati and Tebere. Rényi diversity ordering of nematode genera [42] in the two regions was conducted using the *Rényi* function in R vegan package. The Rényi diversity index represents four indices (species richness, Shannon, Simpson and Berger-Parker indices) and gives a scalable comparison of diversity at four scale parameter (α) values. At 0, 1, 2 and infinity, the value of the Rényi index represents the logarithm of species richness, Shannon index, logarithm of the reciprocal Simpson index and Berger-Parker index, respectively. If the diversity profiles intersect, the communities cannot be unequivocally ordered. When there is no intersection of the profiles, a community is more diverse if its profile is above the other one [43,44]. Additive diversity partitioning [45] of genus richness, Shannon and Simpson diversity indices was used to compute the contribution of α and β components to overall γ diversity using vegan package. Spatial distribution of nematode communities in Nyangati and Tebere was examined using Jaccard index-based non-metric multidimensional scaling (NMDS). Differences between the two regions were assessed using permutational multivariate analysis of variance (PERMANOVA) and permutational multivariate analysis of dispersion (PERMDISP) [46–48]. Relationships between nematode genera abundance and soil properties were determined using canonical correspondence analysis (CCA). Vegan package in R was used for NMDS and CCA analyses. All analyses were done in R version 4.0.2 [49].

Table 1
Mean number of nematode genera in 250 g of soil from Nyangati and Tebere, Kirinyaga, Kenya. Cp-Colonizer-persister values from 1 to 5. Pr – predators, Ba – bacterivores, Fu-fungivores, Pp – herbivores and Om – omnivores. SE - standard error.

Genus	Cp value	Functional guild	Nyangati		Tebere		F value	P value
			Mean	SE	Mean	SE		
Panagrellus	1	Ba$_1$	7.9	6.6	3.9	3.9	0.3	0.6
Rhabditis	1	Ba$_1$	19.8	5.1	22.2	8.9	0.6	0.5
Acrobeloides	2	Ba$_2$	2.6	2.6	5.3	3	0.9	0.4
Anaplectus	2	Ba$_2$	13.1	5.7	4	2.1	1.1	0.3
Aphelenchoides	2	Fu$_2$	1.3	1.3	15.7	6.4	4.1	0.05[a]
Cephalobus	2	Ba$_2$	4	2.1	2.7	1.8	0.2	0.6
Eucephalobus	2	Ba$_2$	3.9	2.8	1.3	1.3	0.5	0.5
Heterocephalobus	2	Ba$_2$	9.1	5.7	17.1	5.7	2.1	0.2
Helicotylenchus	3	Pp$_3$	70.4	18.2	15.9	5.2	6.1	0.02[a]
Meloidogyne	3	Pp$_3$	10.5	4.7	10.5	6.3	0.4	0.6
Pratylenchus	3	Pp$_3$	9.2	6.6	0	0	3.3	0.1
Labronema	4	Om$_4$	20.9	8.2	9.2	5.4	1	0.3
Mesodorylaimus	4	Om$_4$	33.9	10.7	34	12.7	0.3	0.6
Mylonchulus	4	Pr$_4$	2.7	1.8	2.6	2.6	0.2	0.7
Prodorylaimus	4	Om$_4$	57.4	13.3	58.7	13.7	0.01	1.0
Aporcelaimus	5	Om$_5$	30	12.4	7.9	4.6	1.2	0.3
Longidorus	5	Pp$_5$	14.3	9	23.7	6.4	5.6	0.03[a]

[a] = P < 0.05 – One-way analysis of variance.

1.2. Results

There were variations in the nematode genera in the two sampled regions. Cumulatively, there were 17 nematode genera in Tebere (16) and Nyangati (17) rice fields. Bacterivores were predominantly in the Ba_2 functional guild and herbivores were mainly represented by Pp_3. *Panagrellus* and *Rhabditis* were the only enrichment opportunist bacterivores. *Aphelenchoides* ($P = 0.052$) and *Longidorus* ($P = 0.026$) occurred in greater abundance in Tebere, and the number of *Helicotylenchus* ($P = 0.020$) was higher in Nyangati. The omnivore, *Prodorylaimus* occurred in high numbers in both regions (Table 1).

From the Rényi diversity profiles, the two regions could not be unequivocally ordered due to crossing of the profiles along the scale parameter (Fig. 2). Genus richness partitioning, showed that the α and β components contributed 33.7% and 66.3% of the γ diversity, respectively. For Shannon and Simpson diversity indices, the largest contribution to overall diversity was from the α component. The observed β diversity for Shannon (37.5% of γ diversity) and Simpson (15.9% of γ diversity) diversity indices was higher than expected ($P < 0.0001$) (Fig. 3).

Soil food web indices were similar across the two regions with MI2-5 ranging between 3.39 and 3.72. Channel and basal indices were below 30% while the EI and SI were above 50%. There was also no variation in metabolic footprints except for fungivore footprint which was significantly higher ($P = 0.041$) in Tebere (Table 2). Based on the EI and SI, the soil food web in both regions was structured, moderately enriched, and with low to moderate disturbance (Fig. 4).

Nematode communities in Nyangati and Tebere were different with an average dissimilarity of 71.8% (Fig. 5; PERMANOVA, $R^2 = 0.06$, $F = 1.8$, $P = 0.02$; PERMDISP, $F = 0.17$, $P = 0.69$). The observed difference in ordination of nematode communities in the two regions was due to differences in abundance of *Aporcelaimus, Helicotylenchus, Labronema, Longidorus, Mesodorylaimus, Prodorylaimus* and *Rhabditis*.

Phosphorus, pH and Electrical Conductivity (EC) were significantly different in the two regions. Tebere had the highest pH ($P = 0.005$) and EC ($P = 0.0001$) while P was high ($P = 0.001$) in Nyangati (Table 3). The first two axes in the CCA of soil properties and abundance of nematode genera accounted for 18.2% of the variation. There was a significant positive correlation between *Aphelenchoides* and EC while *Helicotylenchus* was negatively correlated (Fig. 6). In the CCA examining the relationship between nematode-based indices and soil properties, a significant negative correlation was observed between MI 2–5, SI and K, Zn and sand. The BI was positively correlated with K while the CI showed a significant positive correlation with Na. The first and second axes represented 36% of the observed variation (Fig. 7).

1.3. Discussion

Irrigated rice cropping systems are ecosystems with environmental variables that differentially shape soil communities [27,28]. In this study, *Panagrellus* and *Rhabditis* were the only bacterivorous enrichment opportunists. *Rhabditis* has been previously reported in paddy areas [50] but Korobushkin et al. [25] did not observe the genus in irrigated rice fields. The abundance of enrichment opportunists in the family Rhabditidae may be attributed to increased breakdown of organic matter by bacteria and the availability of labile food sources [27]. In this study, the numbers of *Aphelenchoides* and *Longidorus* were significantly higher in Tebere while the abundance of *Helicotylenchus* was greater in Nyangati. However, *Aphelenchoides* made up a small proportion of the entire nematode community; 0.4% in Nyangati and 6.7% in Tebere. This nematode is generally prevalent in upland rice fields [27,51] while *Longidorus* is more common in irrigated areas [52]. The PPN *Helicotylenchus* made up the highest proportion (22.6%) of nematode genera in Nyangati. High prevalence of *Helicotylenchus* was also reported in the Philippines, where it occurred in 80% of the sampled regions [53]. According to Coyne et al. [22] *Helicotylenchus* is positively correlated to irrigation compared to *Meloidogyne incognita* and *Pratylenchus zeae* as similarly observed by Bambaradeniya et al. [54]. Control of *Helicotylenchus* in Mwea is imperative since it significantly affects rice grain yield [55] and concomitant infection of paddy rice by *Criconemella onoensis* and *H. dihystera* causes 63–72% yield losses [56]. Only one predatory genus, *Mylonchulus* was present in both regions probably due to the negative effects of flooding on
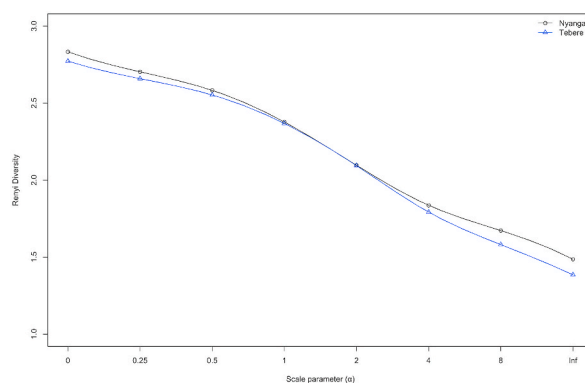

Fig. 2. Rényi diversity profiles of nematode communities in Nyangati and Tebere rice fields in Kirinyaga, Kenya. Scale parameter values are 0-logarithm of species richness, 1- Shannon index, 2- logarithm of the reciprocal Simpson index, and infinity- Berger–Parker index.
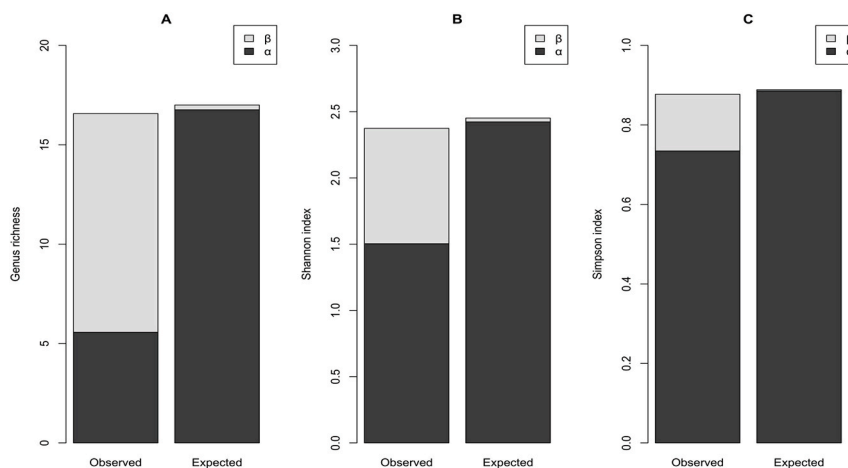
Fig. 3. Additive γ diversity partitioning (alpha, α and beta, β) components) of A) nematode genus richness B) Shannon diversity and C) Simpson diversity index in Nyangati and Tebere rice fields in Kirinyaga, Kenya.

Table 2
Soil food web indices and metabolic footprints (log-transformed) in Nyangati and Tebere rice fields in Kirinyaga, Kenya.

Index/footprint	Nyangati		Tebere		F value	P value
	Mean	SE	Mean	SE		
Maturity Index (MI)	3.34	0.13	3.03	0.17	2.28	0.14
Maturity Index 2–5 (MI2-5)	3.72	0.14	3.39	0.14	2.55	0.12
Plant-Parasitic Index (PPI)	2.99	0.24	3.8	0.34	1.2	0.28
Channel Index (CI)	6.67	6.67	28.5	11.66	3.26	0.08
Basal Index (BI)	7.82	3.87	9.75	2.44	1.27	0.27
Enrichment Index (EI)	58.09	11.02	54	10.07	0.04	0.84
Structure Index (SI)	91.62	3.86	86.54	3.28	0.48	0.5
Composite footprint	6.02	0.2	5.68	0.21	1.43	0.24
Enrichment footprint	2.81	0.51	2.69	0.51	0.03	0.87
Structure footprint	5.28	0.3	4.59	0.28	2.78	0.1
Herbivore footprint	3.38	0.48	3.88	0.46	0.57	0.45
Fungivore footprint	0.06	0.06	0.48	0.19	4.58	0.04[a]
Bacterivore footprint	3.83	0.33	3.8	0.32	0.01	0.95
Predator footprint	0.31	0.21	0.2	0.2	0.16	0.7
Omnivore footprint	5.26	0.31	4.4	0.4	2.97	0.1

[a] = $P < 0.05$– One-way analysis of variance.

predaceous nematodes [25]. The extraction method used in this study favored the extraction of majority of genera from the nematode community but is not optimal for extraction of some genera that have low motility.

Soil food web indices were similar across the two regions with the CI and BI having values below 30% while the EI and SI were above 50%. Contrary to these observations, Korobushkin et al. [25] reported significant regional effects on EI and SI in rice fields. Similar to observations made in this study, Okada et al. [27] reported high SI values with great abundance of cp 3–5. Moderate values of EI that were observed in both Nyangati and Tebere are expected due to fertilizer application that increases the level of fertility and consequently the number of enrichment opportunists [57]. In addition, under irrigated conditions in rice fields, bacterial decomposition is dominant and organic matter from rice litter acts as a source of nutrients to cp1 bacterviroes which is reflected in high EI [27]. Rice cultivation as with other forms of agriculture comprise a source of disturbance to soil nematode communities and food web structure [24]. Based on the EI, there was moderate disturbance in Nyangati and Tebere, probably due to fertilizers and pesticides application [12]; however, the soil food web showed some level of complexity due to the presence of omnivorous nematodes which also contributed to the observed high SI [57]. The intensive use of fertilizers and pesticides in Mwea rice fields is increasing [4,58] which forms a potential source of disturbance that can reduce the complexity of the nematode soil food web [9].

The omnivores, *Prodorylaimus, Labronema, Mesodorylaimus* and *Aporcelaimus* were present in both regions. They belong to cp4 and cp5 groups which are sensitive to disturbance—the observed high number is therefore unexpected although it has been observed in other studies [27,28]. Sinh et al. [59] hypothesized that an increased population of omnivores in paddy rice fields receiving chemical fertilizers may be due to an increase in food supply. Nematodes in higher trophic groups have a regulatory role against PPN [15] and it is therefore important that low levels of disturbance are maintained in Nyangati and Tebere in order to sustain a structured food web that suppresses the parasitic nematodes. In both regions, the channel index was low which is indicative of low levels of complex material and the reduced role of fungivores in decomposition [57]. Fungivore footprint was also reduced which may be due to the
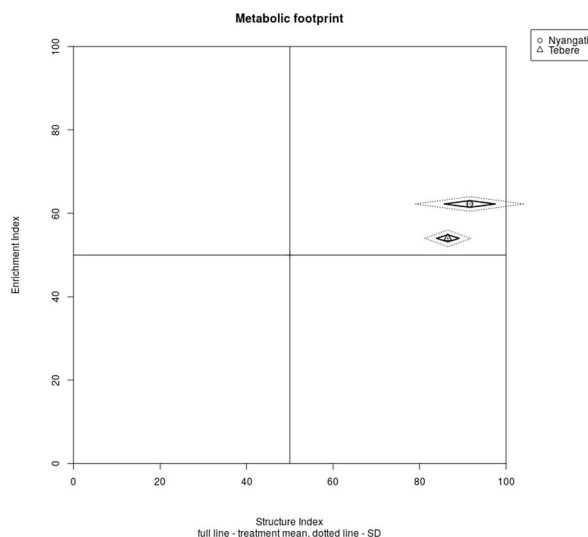
Fig. 4. Soil food web condition in Nyangati and Tebere rice fields in Kirinyaga, Kenya based on the enrichment and structure indices.
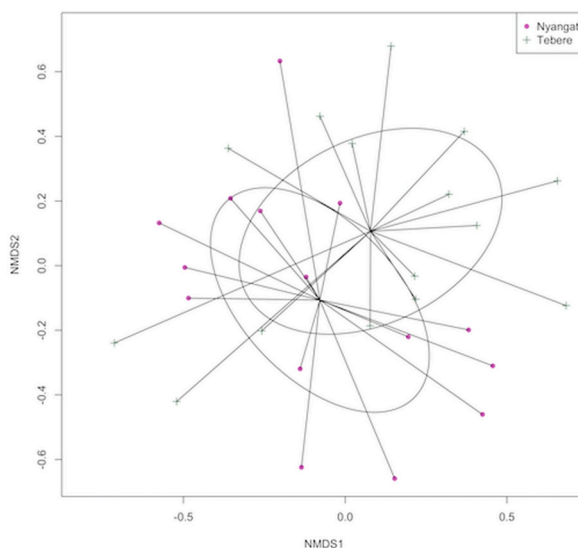

Fig. 5. Non-metric multidimensional scaling ordination of nematode communities in rice fields in Nyangati and Tebere, Kirinyaga, Kenya (PER-MANOVA: P = 0.02; NMDS Stress = 0.2).

anaerobic conditions in paddy fields that inhibit fungal growth [23].

Diversity partitioning of Shannon and Simpson diversity indices showed a higher contribution of α component while between region differences (β) contributed more to genus richness. In addition, Rényi diversity profiles could not be unequivocally ordered due to overlap in nematode diversity measures. Nematode alpha and beta diversity can be affected by variables such as soil, climate [60] and agricultural intensification [61]. In this study, regional variability may have been a stronger driver of differences in specific nematode genera than on the computed diversity indices. This was shown in the NMDS where certain nematode genera had a greater contribution to the dissimilarity between regions. Some of the genera showed correlation with soil properties. Soil pH and EC, which are linked to salinity, are properties that greatly influence nematode communities in paddy rice fields. Nguyen et al. [51] observed that bacterial and fungal feeders were positively correlated to EC while PPN showed a negative correlation which was not significant. Enrichment opportunists in the cp2 class can tolerate soils with high EC [28]. This may explain the positive correlation that was observed between *Aphelenchoides* and EC. The tolerance of this genera to high salinity was also reported in rice fields with alluvial soils containing high salt content [28]. Contrary to our results, Wang et al. [62] did not observe a correlation between the structure index, K, Zn and sand. In the same study the CI was negatively correlated with Na unlike our observations. A positive correlation between silt and structure index was reported by Landi et al. [63]. Correlation of specific nematode indices with soil properties provides an insight

Table 3
Soil physico-chemical properties of Nyangati and Tebere rice fields in Kirinyaga, Kenya.

Soil property	Nyangati		Tebere		F value	P value
	Mean	SE	Mean	SE		
pH (H$_2$O)	6.2	0.2	6.9	0.2	9.3	0.005[a]
Total Nitrogen (%)	0.3	0.01	0.3	0.01	2.3	0.1
Total Organic Carbon (%)	3.1	0.1	2.8	0.2	2.0	0.1
Phosphorus (mg kg^{-1})	38.4	2.4	23.8	3.3	12.9	0.001[a]
Potassium (mmol L^{-1})	0.2	0.03	0.4	0.1	3.6	0.1
Calcium (mmol L^{-1})	19.6	3.1	24.7	4.3	1	0.3
Magnesium (mmol L^{-1})	5.6	0.1	5.4	0.2	0.6	0.5
Manganese (mmol L^{-1})	0.9	0.1	0.7	0.04	7.3	0.01[a]
Copper (mg kg^{-1})	3.1	0.3	2.9	0.4	0.1	0.7
Iron (mg kg^{-1})	206.3	32.1	146.5	46.1	1.1	0.3
Zinc (mg kg^{-1})	2.4	0.2	2.8	0.3	1	0.3
Sodium (mg kg^{-1})	1	0.3	1.2	0.3	0.3	0.6
Electrical Conductivity (mS cm^{-1})	–	–	0.7	0.1	138.7	<0.0001**
Sand (%)	16	0.3	26	4.9	3.6	0.1
Clay (%)	71	1.7	62	4.9	3.2	0.1
Silt (%)	12	1.6	12	1.2	0.01	1

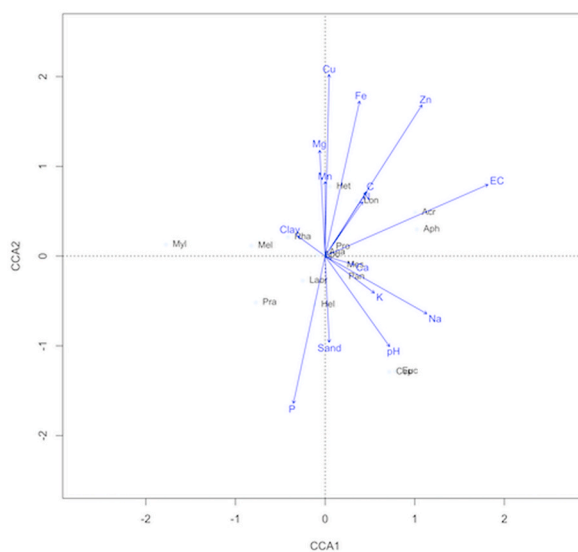[a] = P < 0.05, ** = P < 0.001.

Fig. 6. Canonical correspondence analysis of nematode genera abundance and soil properties in Nyangati and Tebere, Kirinyaga, Kenya. First and second axis eigenvalues are 0.21 and 0.20, respectively. Acr-*Acrobeloides*, Ana-*Anaplectus*, Aph-*Aphelenchoides*, Apo-*Aporcelaimus*, Cep-*Cephalobus*, Euc-*Eucephalobus*, Hel-*Helicotylenchus*, Het-*Heterocephalobus*, Labr-*Labronema*, Lon-*Longidorus*, Mel-*Meloidogyne*, Mes-*Mesodorylaimus*, Myl-*Mylonchulus*, Pan-*Panagrellus*, Pra-*Pratylenchus*, Pro-*Prodorylaimus*, Rha-*Rhabditis*.

into the role of various nematode groups in nutrient cycling [62]. Several other factors that were not assessed in the current study such as climatic variables and their interactions with nematodes, soil properties and other organisms may also affect nematode community dynamics in the rice fields. Changes in cropping practices and the type of rice cultivar may also increase PPN damage in rice [18].

2. Conclusion

Nematode diversity in Nyangati and Tebere was low with the highest contribution being from fields within a region but a few genera showed differences in abundance between regions. The soil food web structure in both regions was enriched due to the presence of enrichment opportunists and it was also structured with moderate disturbance. Integrated nematode management schemes should be put in place to control PPN genera that were identified in this study — some of which cause significant yield losses in rice. The baseline information on the status of nematode-based soil food web provided in this study can be used in the development of sustainable rice cropping systems.
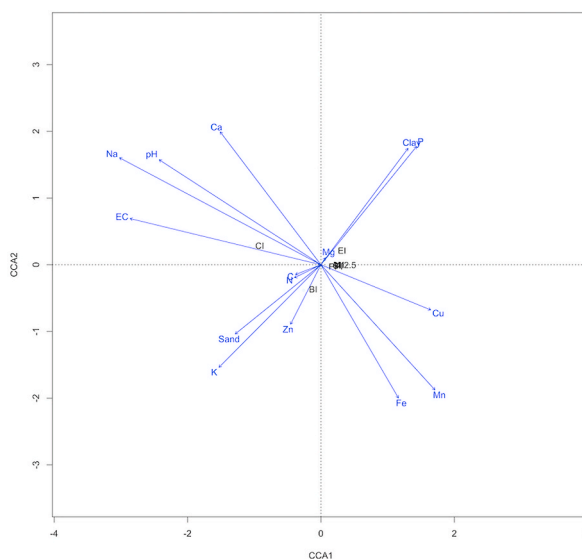
Fig. 7. Canonical correspondence analysis of soil properties, Structure index (SI), Plant-Parasitic Index (PPI), Maturity Index (MI), Maturity Index of nematodes in cp2-5 (MI2-5) (overlapping labels), Channel Index (CI), Basal Index (BI) and Enrichment index (EI) in Nyangati and Tebere, Kirinyaga, Kenya.

Author contribution statement

Dorcas Mokuah: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Hannah Karuri: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Justine Nyaga: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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