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ORIGINAL PAPER

The Combined Application of Organic Materials and Chemical Fertilizer Mitigates the Deterioration of the Trophic Structure of Nematode Community by Increasing Soil N Concentration

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Abstract
The application of chemical fertilizer alone may deteriorate the trophic structure of soil nematode community. However, little is known about whether the combined application of organic materials and chemical fertilizer can mitigate the negative effect, and the mechanism that potentially mitigates the negative effect remains poorly understood. In this study, four fertilization regimes, including unfertilized control (CK), chemical nitrogen (N), phosphorus (P) and potassium (K) fertilizer (NPK), crop straw combined with NPK (SNPK), and pig manure combined with NPK (MNPK), were used to determine the variations in soil nematode trophic groups, diversity, and functional indices under different fertilization regimes. Results indicate that NPK treatment significantly increased the abundances of both bacterivores and plant parasites, and the increase amplitude in the abundance of plant parasites was higher than that of bacterivores under the NPK treatment in comparison to the CK treatment, which might lead to the deterioration of the trophic structure of nematode community. By comparing the difference in the abundance of the plant-parasitic nematode genera among different fertilization regimes, it can be observed that the increase in the abundance of the plant-parasitic nematode-dominant genus *Dolichorhynchus* under the NPK treatment mainly contributed to the increase in the abundance of plant parasites and the subsequent deterioration of the trophic structure of nematode community. Compared to the NPK treatment, SNPK and MNPK treatments suppressed the increase in the abundance of the *Dolichorhynchus*, which will help to mitigate the negative effect of NPK treatment on the trophic structure of nematode community. Moreover, the significantly negative correlation of the *Dolichorhynchus* and soil total nitrogen (TN) indicates that the suppression of this nematode genus is under high N content. Overall, these results suggest that NPK treatment might deteriorate the trophic structure of nematode community mainly by increasing the abundance of the *Dolichorhynchus*, while the combined application of crop straw or pig manure and chemical fertilizer could mitigate the negative effect by suppressing the *Dolichorhynchus* with increasing N concentration, which may be more conducive to maintaining agricultural sustainability.

Keywords Nematode community · Long-term fertilization · Crop straw · Pig manure · Regosol

1 Introduction

Nematodes as the most abundant animals on earth occupy key positions at most trophic levels in soil food webs, and are mainly assigned to the following trophic groups according to their feeding habits: bacterivores, fungivores, plant parasites, predators, and omnivores (Yeates et al. 1993). Of the soil nematode trophic groups, bacterivores and fungivores have been found to be able to enhance the mineralization of soil nutrients based on their interactions with microflora and thus stimulate crop growth (Ingham et al. 1985; Gebremikael et al. 2016), while plant parasites can result in yield losses by feeding on crop roots (Bird and Kaloshian 2003; Sikder and Vestergard 2020).

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Previous studies have found that soil nematodes are sensitive to environmental changes and can be affected by fertilization in agricultural ecosystems (Jiang et al. 2013a; Zhong et al. 2017). It has been widely reported that the application of chemical fertilizer alone or its combined application with organic materials can increase the abundance of soil bacterivores and fungivores by stimulating the growth of soil microorganisms (Jiang et al. 2013a; Zhong et al. 2017; Shaw et al. 2019). However, for the plant parasites, some researchers found that the combined application of organic materials and chemical fertilizer enhanced their abundance by increasing plant root biomass (Li et al. 2018; Shaw et al. 2019), while other researchers observed that the combined application of organic materials and chemical fertilizer suppressed their abundance through the generation of certain harmful substances during the decomposition of organic materials (Oka 2010; Zhong and Zeng 2019).

In addition, previous studies have also reported that soil nematode diversity indices, such as the Shannon–Weaver index (H′), Simpson′s dominance index (λ), and Pielou evenness index (J), can be used to assess the diversity of soil nematode community and its resistance to environmental stress (Biederman and Boutton 2009; Zhang et al. 2009; Pan et al. 2010). The Wasilewska index (WI), a functional index calculated as the ratio of bacterivores and fungivores to plant parasites, can be used to assess the trophic structure of nematode community (Liu et al. 2015, 2016). Liu et al. (2016) reported that the jujube/wheat intercropping system increased the WI value compared to the sole jujube cultural system, and concluded that the wheat improved trophic structure of nematode community by increasing the abundance of bacterivores and reducing that of plant parasites. However, with regard to the changes in the WI value under different fertilization regimes, Hu and Qi (2010) observed that the application of chemical fertilizer alone increased the abundance of both bacterivores and plant parasites compared to unfertilized control while decreased the WI value. This finding was attributed to the high percentage of plant parasites in the chemical fertilizer-treated soil (Hu and Qi 2010), and indicated that the application of chemical fertilizer alone could deteriorate the trophic structure of nematode community. However, since plant parasites have various genus in soil and various genus may respond differently to different fertilization regimes (Zhong et al. 2017; Li et al. 2018; Zhong and Zeng 2019), little is known about which plant-parasitic nematode genera are mainly responsible for the increase in the abundance of plant parasites and the subsequent deterioration of the trophic structure of nematode community in chemical fertilizer-treated soil. Furthermore, Hu and Qi (2010) also found the application of compost increased the WI value compared to the application of chemical fertilizer, and thus mitigated the negative effect of the application of chemical fertilizer alone on the trophic structure of nematode community. However, little is known about whether the combined application of organic materials and chemical fertilizer can also mitigate this negative effect.

Therefore, the objectives of this study were (1) to investigate the response of soil nematode trophic groups, diversity, and functional indices to different fertilization regimes and (2) to explore whether the combined application of organic materials and chemical fertilizer mitigates the negative effect of the application of chemical fertilizer alone on the trophic structure of nematode community and the mechanism underlying this mitigation. This study will be conducive to increasing our understanding of the mechanism that affects the changes in the trophic structure of nematode community under different fertilization regimes and provide a theoretical scientific basis for selecting appropriate fertilization regimes in agricultural ecosystems.

2 Materials and Methods

2.1 Site Description

This study was conducted at the Yanting Agro-ecological Experimental Station of Purple Soil, Chinese Academy of Science in Yanting County, Sichuan Province, China (31° 16′ N, 105° 28′ E, at an altitude of 460 m). The region has a moderate subtropical monsoon climate with a mean annual temperature of 17.3 °C and a mean annual precipitation of 826 mm. The soil in the study area is characterized as a typical purple soil (Regosol in FAO taxonomy), which is developed from Jurassic purplish shale and is widely distributed in the upper reaches of the Yangtze River (Zhu et al. 2009).

2.2 Experimental Design

The experiment was initiated in 2003, and a winter wheat (*Triticum aestivum* L.) planted from late October to May of the next year and summer maize (*Zea mays* L.) planted from May to September cropping rotation was used for all treatments each year during the whole 15 years experiment. The experiment was arranged in a randomized block design with three replications for each treatment. Each experimental plot was 32 m^2 (8 m × 4 m). The treatments included (1) unfertilized control (CK); (2) chemical NPK fertilizer (NPK); (3) crop straw (15% of applied N) combined with chemical NPK fertilizer (85% of applied N) (SNPK); and (4) pig manure (40% of applied N) combined with chemical NPK fertilizer (60% of applied N) (MNPK). All the fertilization regimes received equivalent amounts of N (280 kg N ha^{-1} $year^{-1}$) split into 130 kg N ha^{-1} $year^{-1}$ in the wheat season and 150 kg N ha^{-1} $year^{-1}$ in the maize season, and the chemical N fertilizer applied was ammonium bicarbonate. Additionally, all the fertilization regimes received calcium superphosphate (90 kg P_2O_5 ha^{-1} equivalent) and potassium chloride (36 kg K_2O ha^{-1} equivalent) as basal fertilization in both the wheat and the maize growth seasons. The average nutrient concentrations in the crop straw and pig manure were measured every year, and the application amounts for the crop straw and pig manure were calculated based on the N concentration in the straw and manure. All the chemical fertilizers and organic materials were applied into the topsoil at 15 cm depth manually and once as basal fertilization at the beginning of each crop season. Each plot received the same amount of N, P_2O_5, and K_2O each year during the whole experiment. For the SNPK treatment, the straw stalks were cut into small pieces of approximately 5 cm in length and then incorporated into the treatment plots.

2.3 Soil and Crop Root Sampling and Analysis

Soil and crop root samples were collected when the maize was harvested in September 2018. For the soil samples, five soil cores in each plot were randomly sampled at a 0–15 cm depth and combined to make a composite sample. A portion of the soil samples was stored at 4 °C for soil microbial biomass carbon (MBC) analysis and nematode identification. The remaining samples were air-dried for soil total N (TN) and pH analysis. Soil MBC was determined by the fumigation-extraction method (Vance et al. 1987). Soil TN was measured with an elemental analyzer (Vario MICRO cube analyzer, Elementar, Germany). Soil pH was measured using a 1:2.5 (w:v) soil:water suspension ratio. For the crop root samples, four maize roots were randomly collected from each plot. Before calculating the root biomass, the collected roots were oven-dried at 65 °C until the sample weight no longer fluctuated.

Nematodes were extracted from 50 g fresh soil by a modified cotton-wool filter method (Townshend 1963). Nematode abundance was expressed as individuals per 100 g dry soil. After counting total nematode abundance in each sample, 100 individuals were randomly selected and identified to genus level using an inverted compound microscope. When total nematodes were fewer than 100 in a sample, all nematodes in that sample were identified. Then, the nematodes were divided into the following trophic groups according to their feeding habits: bacterivores (Ba), fungivores (Fu), plant parasites (PP), predators, and omnivores (Yeates et al. 1993).

2.4 Nematode Community Analysis

The characteristics of nematode community were described using the following indices: (1) the Shannon–Weaver index (H′), $H' = -\sum P_i \ln P_i$, where P_i is the proportion of the individuals of i-th group in the community (Shannon and Weaver 1949); (2) the Simpson′s dominance index (λ), $\lambda = \sum P_i^2$ (Simpson 1949); (3) the Pielou evenness index (J), $J = H'/\ln S$, where S is the total number of nematode genera in the community (Pielou 1975); and (4) the Wasilewska index (WI), $WI = (Fu + Ba)/PP$ (Wasilewska 1994).

2.5 Statistical Analysis

The Duncan's test at the $P = 0.05$ significance level and one-way ANOVA were used to analyze the effects of different fertilization regimes on soil properties, crop root biomass, nematode trophic groups, and the nematode indices. The correlations between soil biochemical parameters, root biomass, and nematode properties are evaluated based on Pearson's correlation coefficients. Differences at the $P < 0.05$ level were considered significant. All statistical analyses were conducted with SPSS 16.0 software (SPSS, Chicago, IL, USA).

3 Results

3.1 Response of Soil Properties and Root Biomass to Different Fertilization Regimes

Compared to the unfertilized control, all the fertilization regimes significantly increased soil microbial biomass C, total N concentrations, and crop root biomass and decreased soil pH (Table 1). Among the fertilization regimes, soil total N showed significantly higher concentration under SNPK and MNPK treatments than under NPK treatment (Table 1).

Table 1 Soil properties and crop root biomass under different fertilization regimes

	CK	NPK	SNPK	MNPK
MBC (mg kg^{-1})	63.5 ± 32.6b	136.3 ± 57.5a	197.4 ± 23.9a	176.7 ± 23.1a
TN (g kg^{-1})	0.81 ± 0.04c	1.03 ± 0.03b	1.21 ± 0.07a	1.21 ± 0.05a
pH	8.31 ± 0.07a	7.97 ± 0.15b	7.89 ± 0.01b	8.07 ± 0.08b
RB (t ha^{-1})	0.18 ± 0.07a	0.50 ± 0.16b	0.65 ± 0.22b	0.65 ± 0.13b

MBC, soil microbial biomass carbon; *TN*, soil total nitrogen; *RB*, crop root biomass; *CK*, unfertilized control; *NPK*, chemical nitrogen (N) and phosphorus (P) plus potassium (K); *SNPK*, crop straw combined with NPK; *MNPK*, pig manure combined with NPK. Values are the mean ± standard deviation of three replicates, and values followed by different letters within a row indicate difference ($P < 0.05$) among different fertilization regimes

3.2 Response of Soil Nematode Trophic Groups to Different Fertilization Regimes

Compared to unfertilized control, NPK and SNPK treatments significantly increased the abundances of bacterivores and plant parasites. However, there was no significant difference in the abundance of soil nematode trophic groups between MNPK and CK treatments (Fig. 1).

3.3 Response of Soil Plant-Parasitic Nematode Genera to Different Fertilization Regimes

Thirteen plant-parasitic nematode genera were identified in this study, of which *Tylenchorhynchus*, *Pratylenchus*, *Dolichorhynchus*, and *Malenchus* were the dominant plant-parasitic nematode genera (relative abundance > 10%) with relative abundances of 25.5%, 19.2%, 16.9%, and 10.9%, respectively (Table 2). *Helicotylenchus* and *Telotylenchus* were the plant-parasitic nematode subdominant genera (relative abundance > 5%) with relative abundances of 9.1% and 8.5%, respectively (Table 2). Of these genera, *Pratylenchus* and *Malenchus* showed significantly higher abundances under the SNPK and MNPK treatments than under the CK treatment, while *Dolichorhynchus* showed significantly lower abundance under the CK, SNPK, and MNPK treatments than under the NPK treatment. There was no significant difference in the abundance of *Dolichorhynchus* among the CK, SNPK, and MNPK treatments (Table 2).

3.4 Response of Soil Nematode Diversity and Functional Indices to Different Fertilization Regimes

Fertilization treatment significantly affected the λ, J, and WI, while there was no significant difference in the H′ value among all the treatments (Fig. 2). Compared to the unfertilized control, the NPK treatment significantly decreased the J and WI values, while SNPK treatment significantly increased the J value and decreased the λ value compared to NPK treatment (Fig. 2).

3.5 Correlations Between Soil Properties, Root Biomass, and Nematode Trophic Groups

Bacterivores were significantly positively correlated with soil microbial biomass C while plant parasites were significantly positively correlated with crop root biomass (Table 3). Both bacterivores and plant parasites were significantly negatively correlated with soil pH (Table 3). Of the dominant and subdominant plant-parasitic nematode genera, *Tylenchorhynchus*, *Pratylenchus*, *Malenchus*, and *Telotylenchus* showed significantly positive correlations with crop root biomass and significantly negative correlations with soil pH (Table 4). Moreover, *Pratylenchus* and *Malenchus* also showed significantly positive correlations with TN. Unlike *Tylenchorhynchus*, *Pratylenchus*, *Malenchus*, and *Telotylenchus*, *Dolichorhynchus* only showed a significantly negative correlation with TN (Table 4).

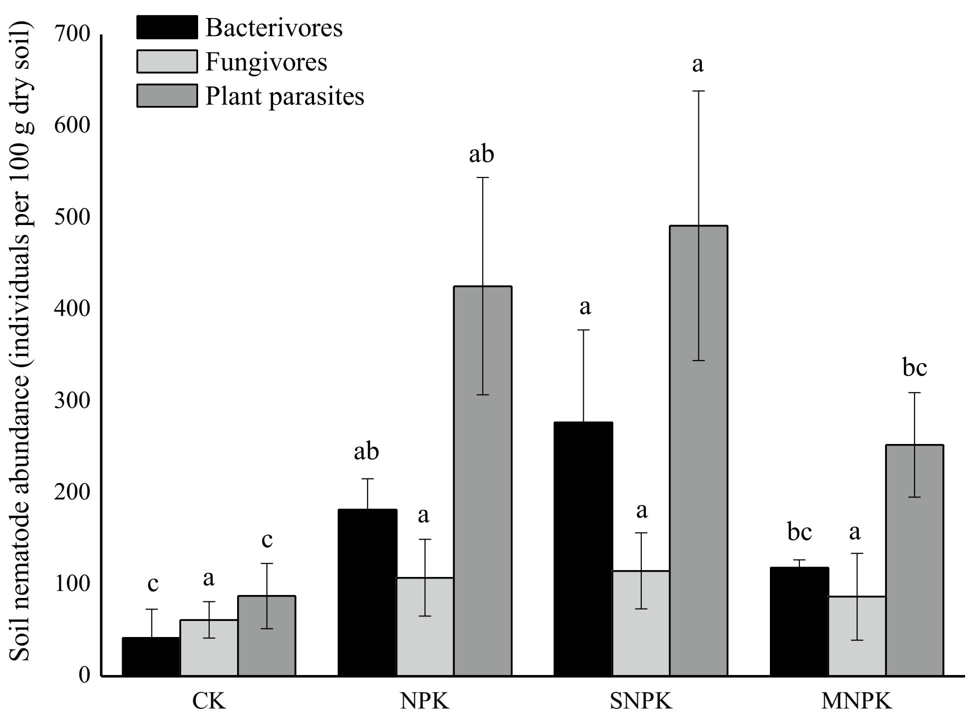

Fig. 1 Abundance of the nematode trophic groups under different fertilization regimes. Values are means and error bars represent standard deviation of three replicates. Bars followed by different lowercase letters indicate difference ($P < 0.05$) among different fertilization regimes. CK, unfertilized control; NPK, chemical nitrogen (N) and phosphorus (P) plus potassium (K); SNPK, crop straw combined with NPK; MNPK, pig manure combined with NPK

Table 2 The abundances of soil plant-parasitic nematode genera under different fertilization regimes

Plant-parasitic nematode genera	CK (Individuals per 100 g dry soil)	NPK	SNPK	MNPK
Tylenchorhynchus	0.0 ± 0.0a	104.3 ± 180.6a	111.9 ± 86.3a	103.8 ± 5.2a
Pratylenchus	13.2 ± 11.0b	56.4 ± 32.7ab	95.2 ± 25.9a	76.5 ± 32.3a
Dolichorhynchus	26.8 ± 5.5b	161.3 ± 112.4a	24.0 ± 28.6b	0.0 ± 0.0b
Malenchus	1.7 ± 3.0c	14.0 ± 12.9bc	84.7 ± 24.4a	36.2 ± 16.1b
Helicotylenchus	35.8 ± 24.6a	31.8 ± 48.0a	33.0 ± 29.5a	13.9 ± 20.4a
Telotylenchus	0.0 ± 0.0b	25.7 ± 7.3b	77.3 ± 53.9a	3.6 ± 3.1b
Tylenchus	3.9 ± 4.7a	15.3 ± 2.5a	18.2 ± 15.4a	5.0 ± 5.4a
Aglenchus	0.8 ± 1.5a	4.1 ± 7.2a	23.0 ± 30.0a	3.6 ± 6.2a
Neopsilenchus	0.0 ± 0.0a	10.5 ± 5.7a	17.1 ± 24.6a	1.4 ± 2.5a
Coslenchus	0.0 ± 0.0b	2.1 ± 3.6b	0.0 ± 0.0b	8.5 ± 3.7a
Rotylenchus	2.5 ± 4.4a	0.0 ± 0.0a	5.0 ± 4.6a	0.0 ± 0.0a
Macroposthonia	2.5 ± 4.4a	0.0 ± 0.0a	0.0 ± 0.0a	0.0 ± 0.0a
Ecphyadophora	0.0 ± 0.0a	0.0 ± 0.0a	2.0 ± 3.5a	0.0 ± 0.0a

CK, unfertilized control; *NPK*, chemical nitrogen (N) and phosphorus (P) plus potassium (K); *SNPK*, crop straw combined with NPK; *MNPK*, pig manure combined with NPK. Values are the mean ± standard deviation of three replicates, and values followed by different letters within a row indicate difference ($P < 0.05$) among different fertilization regimes

4 Discussion

4.1 Response of Soil Nematode Trophic Groups to Different Fertilization Regimes

In this study, in comparison to the unfertilized control, the 15-year continuous NPK and SNPK treatments significantly increased the abundances of soil bacterivores and plant parasites, which was consistent with the results obtained by Jiang et al. (2013a), Zhong et al. 2017, and Shaw et al. (2019), and who attributed this to the increase in the amount of food resources for the bacterivores and plant parasites. The significantly positive correlations of soil microbial biomass and crop root biomass with bacterivores and plant parasites in this study also supported this assumption. In addition, the significantly negative correlation of soil pH with bacterivores and plant parasites indicates that the lower soil pH in the NPK and SNPK treatments than in the unfertilized control might be another reason that resulted in the increase in the abundances of bacterivores and plant parasite under the two fertilization treatments, since a previous study found that the higher soil pH could negatively affect the abundances of soil bacterivores and plant parasites by influencing host reactions, soil chemical composition, or nematicidal activity (Liu et al. 2006; Jiang et al. 2013b; Zhang et al. 2016).

In contrast to those in the NPK and SNPK treatments, the bacterivores and plant parasites in the MNPK treatment did not show significant differences in abundance compared to those in unfertilized control, although the MNPK treatment also had significantly higher soil microbial biomass and crop root biomass and lower soil pH than the CK treatment. This inconsistent result could be attributed to the generation of certain harmful substances on soil bacterivores and plant parasites due to the long-term application of pig manure in this study, since it has been reported that the decomposition of pig manure in soils can promote the release of substances that are harmful to soil bacterivores and plant parasites, such as organic acids, phenols, and hydrogen sulfide (Oka 2010; Zhong and Zeng 2019). These substances may have offset the increase in the abundance of soil bacterivores and plant parasites caused by the increase in food sources and the decrease in soil pH under the MNPK treatment.

4.2 Response of Soil Nematode Diversity and Functional Indices to Different Fertilization Regimes

The nematode index H′ is often used to assess the diversity of soil nematodes (Zhang et al. 2009; Pan et al. 2010). Based on the variation in the H′ value among the treatments, it can be observed that all the fertilization treatments did not affect soil nematodes diversity. However, according to the variation in the J and λ values among the treatments, it can been concluded that NPK treatment resulted in less resistance of soil nematode community to environmental stress compared to the CK treatment, while SNPK treatment improved the situation in comparison to the fertilization regime where only chemical fertilizer was applied without organic material addition, since previous studies have reported that nematode communities with a lower evenness were less resistant to disturbance and environmental changes than communities with lower dominance and higher evenness (Biederman and Boutton 2009).

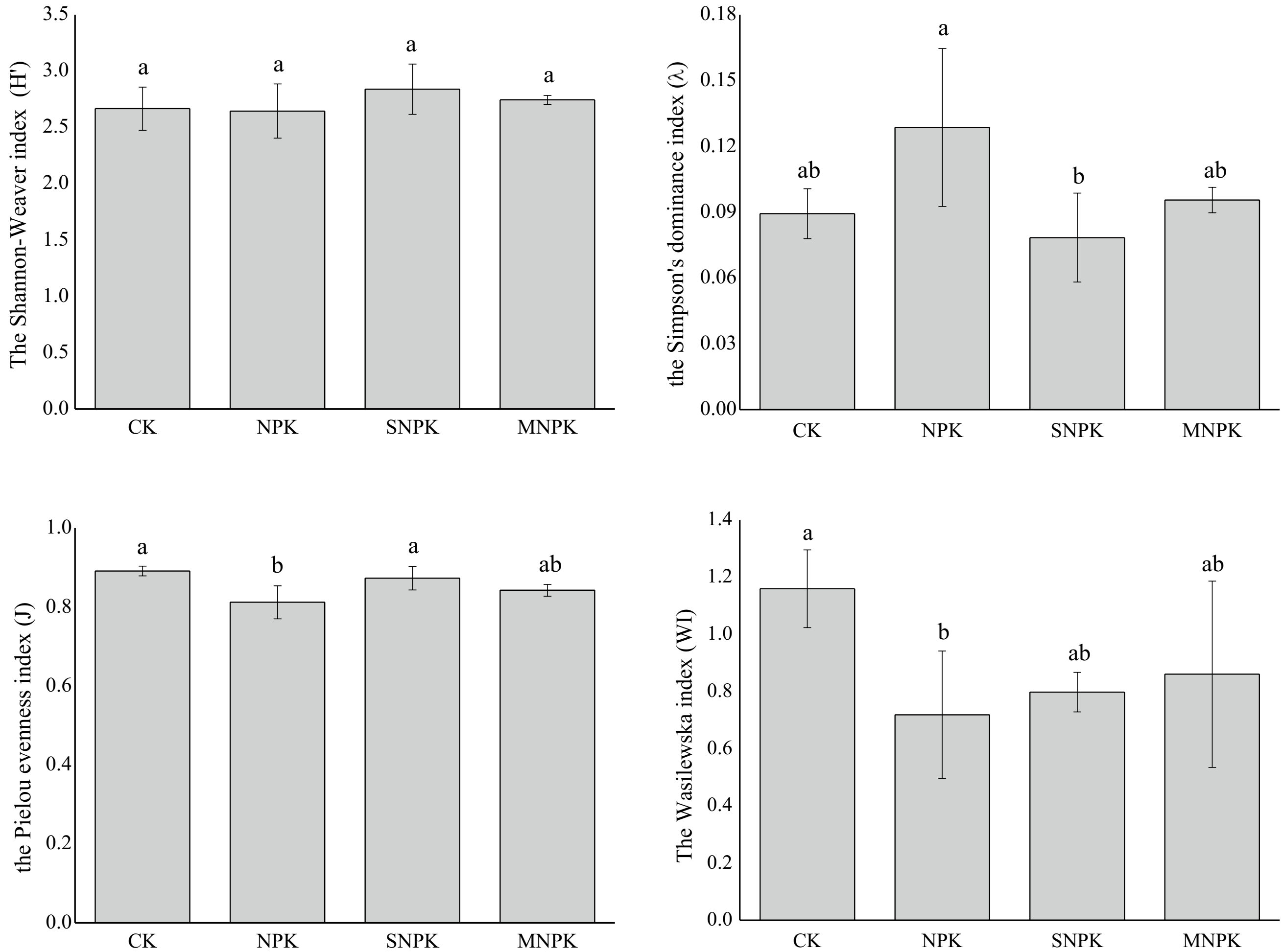

Fig. 2 The nematode diversity and functional indices under different fertilization regimes. Values are means and error bars represent standard deviation of three replicates. Bars followed by different lowercase letters indicate difference ($P<0.05$) among different fertilization regimes. CK, unfertilized control; NPK, chemical nitrogen (N) and phosphorus (P) plus potassium (K); SNPK, crop straw combined with NPK; MNPK, pig manure combined with NPK

Table 3 Correlations between soil properties, root biomass, and nematode trophic groups

	MBC	TN	pH	RB	Ba	Fu	PP
MBC	1						
TN	0.856**	1					
pH	−0.632*	−0.734**	1				
RB	0.715**	0.732**	−0.682*				
Ba	0.652*	ns	−0.758**	0.673*	1		
Fu	ns	ns	ns	ns	ns	1	
PP	ns	ns	−0.820**	0.723**	0.946**	ns	1

MBC, soil microbial biomass carbon; *TN*, soil total nitrogen; *RB*, crop root biomass; *Ba*, bacterivores; *Fu*, fungivores; *PP*, plant parasites

*Correlation is significant at the 0.05 level; **correlation is significant at the 0.01 level

The WI, as the ratio of bacterivores and fungivores to plant parasites, has been used as an indicator to assess the trophic structure of nematode community and the degree of soil health (Liu et al. 2015, 2016). In this study, the significantly lower WI value under the NPK treatment than under the CK treatment indicates the NPK treatment might have

Table 4 Correlations between soil properties, crop root biomass, and plant-parasitic nematode genera

	MBC	TN	Soil pH	RB
Tylenchorhynchus	ns	ns	−0.604*	0.841**
Pratylenchus	ns	0.627*	−0.582*	0.608*
Dolichorhynchus	ns	−0.614*	ns	ns
Malenchus	0.648*	0.705*	−0.693*	0.782**
Helicotylenchus	ns	ns	ns	ns
Telotylenchus	ns	ns	−0.704*	0.602*
Tylenchus	ns	ns	−0.626*	ns
Aglenchus	ns	ns	ns	ns
Neopsilenchus	ns	ns	−0.614*	ns
Coslenchus	ns	ns	ns	ns
Rotylenchus	ns	ns	ns	ns
Macroposthonia	ns	ns	ns	ns
Ecphyadophora	ns	ns	ns	ns

MBC, soil microbial biomass carbon; *TN*, soil total nitrogen; *RB*, crop root biomass

*Correlation is significant at the 0.05 level; **correlation is significant at the 0.01 level

deteriorate the trophic structure of the nematode community. Meanwhile, since the abundances of both bacterivores and plant parasites were significantly higher under the NPK treatment than under the CK treatment, the lower WI value also means that the increase amplitude in the abundance of plant parasites was higher than that of bacterivores under the NPK treatment in comparison to the CK treatment. A similar result was also reported by Hu and Qi (2010) in a chemical fertilizer treated soil. However, this study further explored the increase amplitude of different plant-parasitic nematode genera, and found only the abundance of *Dolichorhynchus* was significantly higher under the NPK treatment than under the CK treatment, which indicates that the increase in the abundance of the plant-parasitic nematode-dominant genus *Dolichorhynchus* under the NPK treatment might mainly lead to the increase in the abundance of plant parasites and the lower WI value in the chemical fertilizer treated soil.

Interestingly, this study observed that SNPK and MNPK treatments could suppress the increase in the abundance of *Dolichorhynchus* in comparison to the fertilization regime where only chemical fertilizer was applied without organic material addition. The suppressive effect of the combined application of organic materials and chemical fertilizer on the *Dolichorhynchus* might be related to the significantly higher soil N concentration under the SNPK and MNPK treatments than under the NPK treatment, since the abundance of *Dolichorhynchus* in this study was found to be only significantly negatively correlated with soil TN by analyzing its relationship with soil pH, MBC, and TN. A suppressive effect of soil N on plant parasites was also found by Wei et al. (2012) in a Calcic Chernozem. However, this study determined that only the abundance of *Dolichorhynchus* was significantly negatively correlated with the soil TN for all nematode genera, indicating that in comparison to other plant-parasitic nematode genera, *Dolichorhynchus* might be more susceptible to the suppressive effect of soil N. Meanwhile, since the increase in the abundance of the *Dolichorhynchus* under the NPK treatment mainly led to the deterioration of the trophic structure of nematode community, the suppressive effect of the combined application of organic materials and chemical fertilizer on the *Dolichorhynchus* could theoretically mitigate the negative effect of NPK treatment on the trophic structure of nematode community. Indeed, this assumption was also supported by the observation that there was no significant difference in the WI value among SNPK, MNPK, and CK treatments.

5 Conclusions

This study explored the effect of the application of chemical fertilizer alone and the combined application of organic materials and chemical fertilizer on soil nematode trophic groups, diversity, and functional indices, and ascertained the main plant-parasitic nematode genus that increased the abundance of plant parasites and led to the deterioration of the trophic structure of nematode community in the chemical fertilizer-treated soil. The results of the current study showed that the application of chemical fertilizer alone significantly increased the abundances of both soil bacterivores and plant parasites compared to the CK treatment, which might have decreased the resistance of soil nematode community to environmental stress and deteriorated the trophic structure of nematode community, of which the increase in the abundance of the plant-parasitic nematode-dominant genus *Dolichorhynchus* mainly led to the deterioration of the trophic structure of nematode community in the chemical fertilizer-treated soil. However, compared to the fertilization regime where only chemical fertilizer was applied without organic material addition, the combined application of crop straw or pig manure and chemical fertilizer not only increased the resistance of soil nematode community to environmental stress, but also mitigated the negative effect of the application of chemical fertilizer alone on the trophic structure of nematode community by suppressing the *Dolichorhynchus* with increasing N concentration, and therefore which may be conducive to maintaining agricultural sustainability.

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Declarations

Conflict of Interest The authors declare no competing interests.

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