Türkiye Tarımsal Araştırmalar Dergisi
dergipark.org.tr/tutad
Research Article
Turk J Agric Res
2025, 12(2): 185-194
© TÜTAD
ISSN: 2148-2306
e-ISSN: 2528-858X
doi: 10.19159/tutad.1706048

# Assessment of Soil Health Using Nematode Communities in Tea [*Camellia sinensis* (L.) O. Kuntze] Plantations of Rize, Türkiye

**Nur SİVRİ[1], Lerzan ÖZTÜRK[2*]**

[1]*Republic of Türkiye Ministry of Agriculture and Forestry, Rize Provincial Directorate of Agriculture and Forestry, Derepazarı District Directorate of Agriculture and Forestry, Derepazarı-Rize, TÜRKİYE*

[2]*Independent Researcher, Süleymanpaşa, Tekirdağ, TÜRKİYE*

**Received:** 25.05.2025 **Accepted:** 25.06.2025

**ORCID ID (By author order)**
orcid.org/0000-0003-3621-6121 orcid.org/0000-0003-2199-6807
*Corresponding Author: lerzanozturk@gmail.com

**Abstract:** In this study soil health in tea [*Camellia sinensis* (L.) O. Kuntze] plantations of Rize Province, Türkiye, was assessed by analyzing nematode community structure and calculating ecological indices and metabolic footprints. On this purpose a survey was carried out in tea growing areas and soil samples were collected from tea growing areas. The nematodes isolated from these soils were identified. Key indicators included the Maturity Index (MI= 2.45), Plant Parasitic Index (PPI= 2.83), and Sigma Maturity Index (ΣMI= 2.56). A total of 36 nematode genera were identified, comprising 13 plant-parasitic and 23 free-living genera. The nematode community was predominantly composed of bacterivores and plant-parasitic taxa, each representing 36.1% of the total population. Omnivores accounted for 16.6%, while fungal feeders and predators each comprised 5.6%. Functional indices reflected a moderately structured and enriched soil food web, with an Enrichment Index of 63.89, Structure Index of 68.16, Basal Index of 16.06, and Channel Index of 24.81. Metabolic footprint analysis revealed a relatively high Composite Footprint, driven primarily by bacterivore and predator contributions, demonstrating active trophic interactions and moderate soil biodiversity. In the soil food web structure a majority of samples were located in the upper-right quadrant, typically reflecting nematode assemblages found in nutrient-enriched and structurally stable soils.

**Keywords:** Nematode community, tea plantations, ecological indices, Channel Index, Structure Index

## 1. Introduction

Tea [*Camellia sinensis* (L.) O. Kuntze], a member of the *Camellia* genus in the Theaceae family, is a perennial and evergreen shrub cultivated primarily for its leaves, which are processed into one of the most widely consumed non-alcoholic beverages globally (Banerjee, 1992). Owing to its cultural, economic, and health significance, tea ranks among the most valuable agricultural commodities in terms of production volume and global consumption. According to the Food and Agriculture Organization (Anonymous, 2024), major tea-producing countries such as Kenya, Sri Lanka, and Vietnam contribute substantially to the global tea market.

In Türkiye, tea cultivation is predominantly concentrated in the eastern Black Sea region, particularly in the provinces of Rize, Trabzon, Artvin, and Giresun (Yurteri et al., 2019). Data from the Turkish Statistical Institute (Anonymous, 2025) indicate that approximately 1.4 million tons of fresh tea leaves were harvested in 2023 from a total of 79.000 hectares. Among these provinces, Rize alone accounts for roughly 69% of national production, making it the epicenter of Turkish tea agriculture.

The perennial nature of tea cultivation and its year-round management practices foster a complex soil ecosystem. Tea plants are susceptible to a wide range of pests, including insects, mites, and nematodes, which can significantly impact productivity (Hazarika et al., 2009). Of particular concern are plant-parasitic nematodes, which cause direct damage by feeding on roots and indirect damage by increasing vulnerability to other pathogens. Without effective management, infestations can result in yield losses exceeding 15% annually (Paul et al., 2018). Globally, several nematode genera are recognized as economically important pests of tea.

In addition to plant-parasitic taxa, tea soils also support diverse communities of free-living nematodes, including bacterivores, fungivores, omnivores, and predators. These functional groups play key roles in nutrient cycling, organic matter decomposition, microbial population control, and the maintenance of soil structure and fertility. As integral components of the soil food web, their diversity and composition are regarded as sensitive indicators of soil health and ecological balance (Yeates et al., 2009).

Despite the national importance of tea agriculture in Türkiye, comprehensive studies on nematode biodiversity particularly involving free-living groups are scarce. To date, only 11 plant-parasitic nematode species have been recorded from tea plantations in the country (Kepenekci and Akgul, 1999). However, the broader nematode community and its implications for soil quality remain poorly understood. Therefore, the aim of this study was to assess soil health in tea-growing areas of Rize Province, Türkiye, by analyzing nematode community composition and calculating ecological indices and metabolic footprints.

## 2. Materials and Methods

### 2.1. Survey in tea plantation

As part of the study, field surveys were carried out in February 2025 in 5 districts of Rize province, where tea cultivation is extensive (Table 1, and Figure 1). Soil samples were collected from 19 tea gardens located in 12 villages (Table 2).

In each garden, soil samples were taken from the root zones of five randomly selected tea plants at a depth of 0-30 cm to represent the rhizosphere. The collected soil samples were homogenized to form a composite sample. During sampling, care was taken to maintain at least a 1 km distance between gardens to ensure reliable assessment of nematode biodiversity and population distribution. The

**Table 1.** The acreage of tea production in Rize (Anonymous, 2025) (ha)

| Districts | Ardeşen | Derepazarı | Fındıklı | Güneysu | Hemşin | Kalkandere |
|---|---|---|---|---|---|---|
| Tea | 7.300 | 1.939 | 4.203 | 3.912 | 385 | 4.048 |
| Districts | Merkez | Pazar | Çamlıhemşin | Çayeli | İkizdere | İyidere |
| Tea | 12.631 | 6.647 | 1.414 | 8.277 | 450 | 1.877 |

Surveyed districts were indicated in pink.

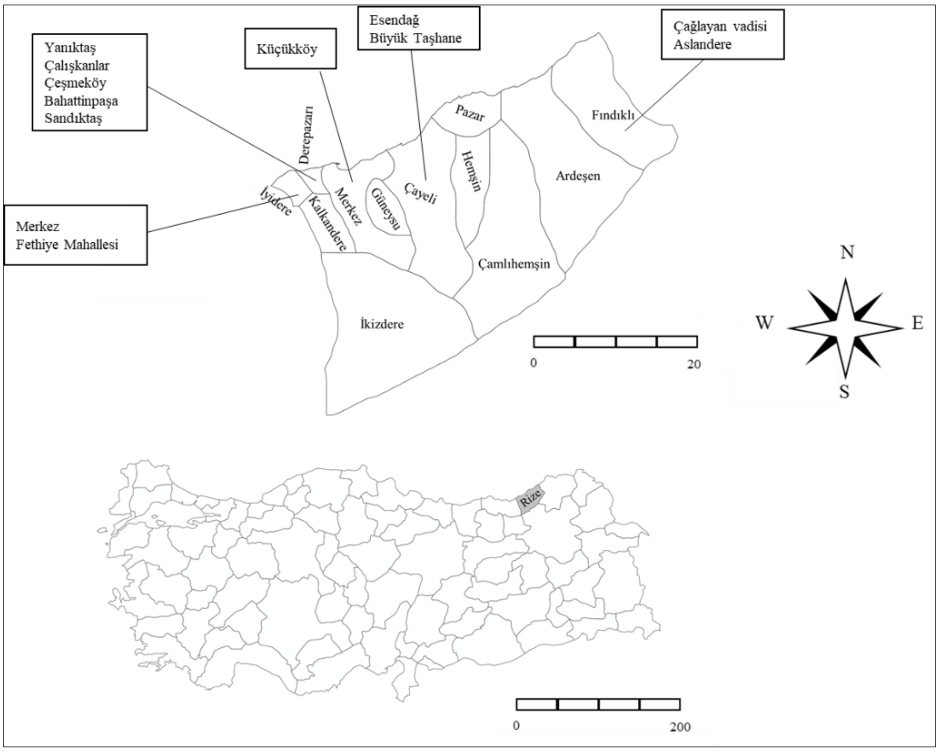


**Figure 1.** Study area map of Rize

collected soil samples were transported to the laboratory under appropriate conditions for nematode extraction and identification.

**Table 2.** Locations of sampled gardens: Districts, villages, number of gardens, and sizes

| Districts | Villages | Number of gardens | Decare per garden |
|---|---|---|---|
| Çayeli | Büyük Taşhane | 1 | 11 |
| | Esendağ | 2 | 12 |
| Fındıklı | Çağlayan Vadisi | 1 | 14 |
| | Aslandere | 1 | 12 |
| Merkez | Küçükköy | 1 | 5 |
| İyidere | Merkez | 1 | 8 |
| | Fethiye Mahallesi | 1 | 10 |
| Derepazarı | Bahattinpaşa | 1 | 7 |
| | Çeşmeköy | 1 | 6 |
| | Çalışkanlar | 1 | 4 |
| | Sandıktaş | 4 | 6 |
| | Yanıktaş | 4 | 7 |

## 2.2. Nematode extraction and identification

Nematodes were isolated from soil samples using modified Baermann Funnel method. In this method, 150 cc plastic containers with sieves inside were used for nematode isolation, and the containers with 100 g soil soil per field were left undisturbed in water for 48 hours to allow nematodes to migrate into the water. At the end of this period, the suspesion containing nematodes were sieved through 400 mesh sieve and nematodes reiamining on the sieve were collected.

Plant-parasitic nematode species were identified based on female specimens, except for *Trichodorus*, where males were also considered. For other free-living nematodes, identification was based on either male or female specimens, depending on the genus. In cases where species determination required female or male that was not isolated from the soil, identification was limited to the genus level. Species identification was performed according to the diagnostic characteristics described by Siddiqi (2000). Morphometric measurements were calculated based on De Man (1876). Polytomous keys of Anderson and Hooper (1970), Anderson (1979), Geraert and Raski (1987), Handoo and Golden (1989), Brzeski (1991), Abolafia and Pena Santiago (1996), Scholze and Sudhaus (2011), Taher et al. (2017), and Palomares-Rius et al. (2022). The identified nematodes were classified based on taxonomic order, colonizer-persister (c-p) value, and trophic group. The frequency of occurrence (F) was calculated using the formula provided in Equation 1.

$$\mathrm{F}(\%) = \frac{n}{N} \times 100 \quad (1)$$

n= Number of samples in which a specific nematode genus/species occurs; N= Total number of samples collected

## 2.3. Soil food, and community analysis of nematodes

Nematodes extracted from tea gardens were subjected to a series of diversity and food web analyses to assess the soil health status in the sampled areas. To evaluate the diversity of nematode fauna in the fields, the Shannon-Weiner diversity index, Evenness, and Richness were calculated. The Shannon-Weiner index was calculated according to Equation 2, while the Evenness Index was determined using Equation 3 (Pielou, 1966; Neher and Darby, 2009).

$$\text{Shannon-Weiner } H' = \sum[(pi) \times log\ (pi)] \quad (2)$$

$$\text{Evenness } J' = \frac{H'}{ln\,(S)} \quad (3)$$

In the formulas, Pi is the relative abundance of a genus, S is the number of genera, and N is the total count of nematode individuals.

The nematode community was analyzed using Maturity (MI), Maturity (MI) 2-5, and Plant Parasitic (PPI) indices. To gain further insights into the soil food web dynamics, several indices were calculated, including Basal Index (BI), Channel Index (CI), Enrichment Index (EI), and Structure Index (SI). These indices were used to assess food web quality, enrichment, and soil disturbance (Ferris et al., 2001).

Indices were calculated using the Nematode Indicator Joint Analysis (NINJA) tool (Sieriebriennikov et al., 2014). The Maturity Index (MI) was used to assess soil disturbance and ecosystem stability: lower MI scores indicate more disturbed soils. The MI2-5 index, was used to evaluate soil health. The EI was used to reflect the level of nutrient input and resource enrichment in the environment. The SI was used to determine the complexity of the soil food web. Meanwhile, the BI was interpreted as a sign of environmental stress; elevated BI values were associated with simplified, degraded soil ecosystems. The CI was applied to differentiate between bacterial and fungal dominated decomposition pathways. High CI values indicated that decomposition was primarily driven by fungal-feeding nematodes, whereas low values pointed to bacterial-feeder dominance in organic matter breakdown (Ferris et al., 2001). To visualize the nematode functional composition and soil food web structure, the Nematode Indicators Joint Analysis (NINJA) software (Sieriebriennikov et al., 2014) was used. This tool was employed to construct the c-p triangle and generate graphical food web representations. Based on nematode community composition, sampling sites were placed into specific quadrants within the c-p framework, following the classification system proposed by Ferris et al. (2001).

## 3. Results and Discussion

### 3.1. Soil nematode diversity in tea plantations

A total of 36 nematode genera were identified in tea orchards in the districts of Çayeli, Derepazarı, Fındıklı, İyidere and Merkez in Rize province. These nematodes were classified into six orders: Aphelenchida, Dorylaimida, Monhysterida, Mononchida, Plectida, Rhabditida, Triplonchida, and Tylenchida, encompassing 22 families. The majority of nematodes belonged to the orders Tylenchida, Rhabditida, and Dorylaimida at the family level the most diverse families in terms of genera were Dorylaimidae, Rhabditidae and Tylenchidae. These findings are consistent with previous studies that emphasized the adaptability of these groups in wide variety of agricultural ecosystems (Khera and Chaturvedi, 1977; Mukherjee and Dasgupta, 1982).

In terms of trophic structure 63.8% of the identified nematodes were free-living including fungivores, bacterivores, omnivores and predators while 36.2% consisted of plant-parasitic genera. The nematode community structure in the studied area was dominated by bacterivorous and plant-parasitic nematodes, each accounting for 36.1% of the total population. Omnivore nematodes constituted 16.6% of the community, while fungal-feeding and predators were comparatively less abundant, each comprising 5.6% of the population (Figure 2). Similar findings were reported by Mukherjee and Dasgupta (1982) and Khera and Chaturvedi (1977), who emphasized the dominance of free-living nematodes in tea soils with frequent organic matter input. The frequent fertilizer applications in these areas create favorable conditions for fast-growing and opportunistic nematodes belonging to this group (Li et al., 2014).

Table 3 represent nematode genera, their trophic groups, c-p classes, and frequency of occurances. In particular, bacterivorous nematodes dominated the nematode fauna in Rize tea plantations, mainly represented by *Rhabditis* (73.68%), *Monhystera* (36.84%), and *Cephalobus* (63.15%). Bacterivorous nematodes mainly Rhabditis, *Monhystera*, and *Cephalobus* were especially prevalent, likely due to the influence of organic matter inputs and fertilizer applications (Table 3). These genera, characterized by low c-p values (1 and 2), point to nutrient enrichment and moderate

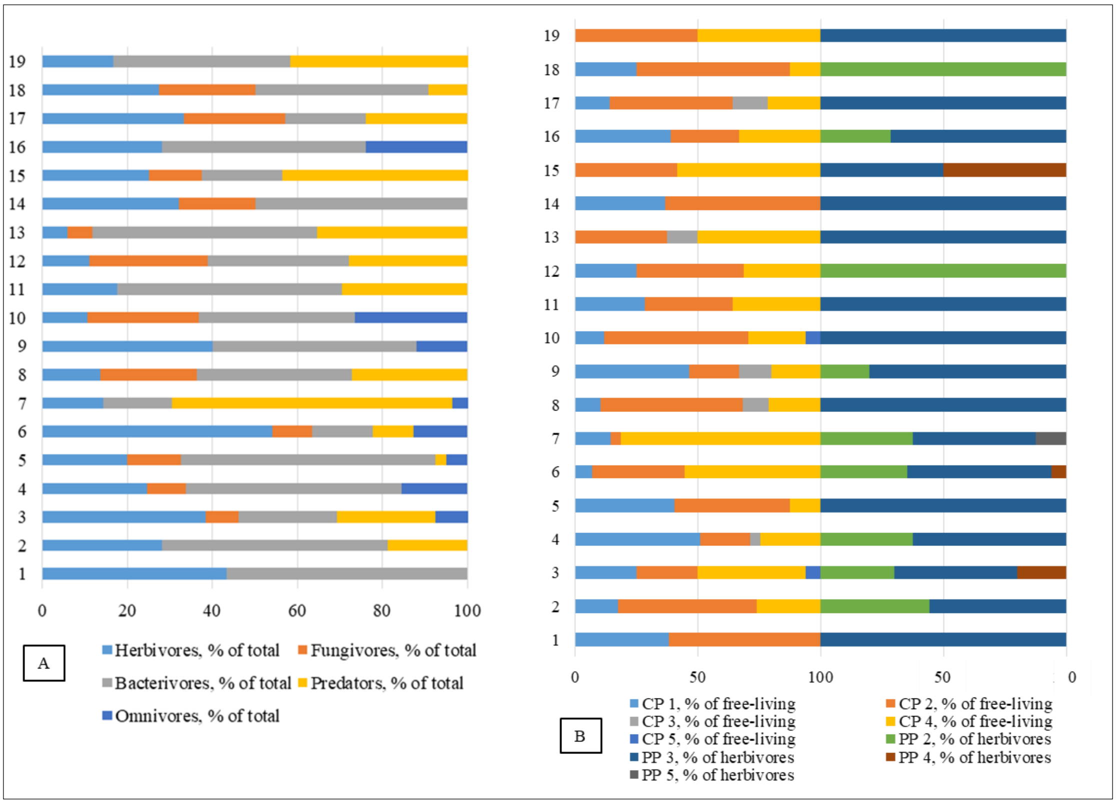


**Figure 2.** Charts representing: (A) Percentage distribution of nematodes based on trophic groups in each garden, (B) Percentage distribution of nematodes based on c-p values in each garden

**Table 3.** Nematode genera identified in tea plantations in Rize

| Genera | Order | Families | Trophic group | c-p | % F |
|---|---|---|---|---|---|
| *Acrobeloides* | Rhabditida | Cephalobidae | Bacterivore | 2 | 15.78 |
| *Alaimus* | Dorylaimida | Alaimidae | Bacterivore | 2 | 10.52 |
| *Anaplectus* | Plectida | Plectidae | Bacterivore | 2 | 5.26 |
| *Cervidellus* | Rhabditida | Cephalobidae | Bacterivore | 2 | 5.26 |
| *Cephalobus* | Rhabditida | Cephalobidae | Bacterivore | 2 | 63.15 |
| *Cruznema* | Rhabditida | Rhabditidae | Bacterivore | 1 | 10.52 |
| *Mesorhabditis* | Rhabditida | Rhabditidae | Bacterivore | 1 | 5.26 |
| *Monhystera* | Monhysterida | Monhysteridae | Bacterivore | 2 | 36.84 |
| *Plectus* | Plectida | Plectidae | Bacterivore | 2 | 10.52 |
| *Panagrolaimus* | Rhabditida | Rhabditidae | Bacterivore | 1 | 5.26 |
| *Prismatolaimus* | Triplonchida | Prismatolaimidae | Bacterivore | 3 | 15.78 |
| *Rhabditis* | Rhabditida | Rhabditidae | Bacterivore | 1 | 73.68 |
| *Wilsonema* | Plectida | Plectidae | Bacterivore | 2 | 5.26 |
| *Aphelenchus* | Aphelenchida | Aphelenchidae | Fungivore | 2 | 10.52 |
| *Ditylenchus* | Tylenchida | Anguinidae | Fungivore | 2 | 10.52 |
| *Aporcelaimellus* | Dorylaimida | Aporcelaimidae | Omnivore | 5 | 10.52 |
| *Dorylaimus* | Dorylaimida | Dorylaimidae | Omnivore | 4 | 5.26 |
| *Eudorylaimus* | Dorylaimida | Quadsinematidae | Omnivore | 4 | 21.04 |
| *Laimydorus* | Dorylaimida | Dorylaimidae | Omnivore | 4 | 10.52 |
| *Mesodorylaimus* | Dorylaimida | Dorylaimidae | Omnivore | 5 | 5.26 |
| *Prodorylaimus* | Dorylaimida | Dorylaimidae | Omnivore | 4 | 36.84 |
| *Clarkus* | Mononchida | Mononchidae | Predator | 4 | 52.63 |
| *Tripyla* | Triplonchida | Tripylidae | Predator | 3 | 10.52 |
| *Boleodorus** | Tylenchida | Tylenchidae | Plant-parasitic | 2 | 10.52 |
| *Coslenchus** | Tylenchida | Tylenchidae | Plant-parasitic | 2 | 26.30 |
| *Criconema* | Tylenchida | Criconematidae | Plant-parasitic | 3 | 5.26 |
| *Filenchus** | Tylenchida | Tylenchidae | Plant-parasitic | 2 | 47.03 |
| *Helicotylenchus* | Tylenchida | Hoplolaimidae | Plant-parasitic | 3 | 31.57 |
| *Geocenamus* | Tylenchida | Merliniidae | Plant-parasitic | 3 | 42.10 |
| *Hemicycliophora* | Tylenchida | Hemicycliophoridae | Plant-parasitic | 3 | 5.26 |
| *Paratylenchus* | Tylenchida | Tylenchulidae | Plant-parasitic | 2 | 5.26 |
| *Pratylenchus* | Tylenchida | Pratylenchidae | Plant-parasitic | 3 | 31.57 |
| *Trichodorus* | Triplonchida | Trichodoridae | Plant-parasitic | 4 | 15.78 |
| *Tylenchus** | Tylenchida | Tylenchidae | Plant-parasitic | 2 | 5.26 |
| *Xiphinema* | Dorylaimida | Longidoridae | Plant-parasitic | 5 | 5.26 |
| *Zygotylenchus* | Tylenchida | Pratylenchidae | Plant-parasitic | 3 | 10.52 |

*: RFF: Root-fungal feeder, c-p: Colonizer-persister class, F %: Frequency of occurance

disturbance common under long-term monoculture. This interpretation aligns with earlier findings in tea soils globally (Mukherjee and Dasgupta, 1982; Kouser et al., 2022). In majority of gardens bacterivores were leading as well as c-p 2 groups.

Table 4 presents the frequency of occurrence and feeding behaviour of plant-parasitic nematode species identified in the surveyed fields. Plant-parasitic nematode diversity was considerable in tea plantations, with 13 genera and 13 species identified. Among these, *Filenchus filiformis*, *Geocenamus rugosus*, and *Helicotylenchus digonicus* were the most prevalent. Importantly, several species (*Trichodorus similis*, *Pratylenchus penetrans*, *Xiphinema pachtaicum*) were recorded for the first time in tea plantations in Türkiye, expanding the known biogeographical range of these economically significant taxa (Table 4). Comparisons with previous studies (e.g., Kepenekci and Akgul, 1999) show an increase in known genera from 10 to 13, with the addition of *Criconema*, *Hemicycliophora*, *Trichodorus*, *Tylenchus*, and *Xiphinema* in this study. Thirteen species were recorded in total, with *Filenchus filiformis* being the most frequently encountered species (47.03%), followed by *Geocenamus rugosus* (42.10%) and *Filenchus thornei* (36.84%) (Table 4). These species are commonly reported from tea-growing regions worldwide (Huan, 1983; Orisajo, 2012) and are known for their adaptability to diverse soil conditions. Most of the species (seven out of thirteen) were classified as ectoparasites. Migratory endoparasites were detected at moderate frequencies (10.52-21.05%), whereas migratory ectoparasites occurred at relatively low frequencies (5.26-15.78%). *Paratylenchus nainianus*, an obligate ectoparasite, was the least frequent species observed (5.26%) (Table 4).

Soil pH, which is typically low (below pH 5) in tea plantations of Rize (Özyazıcı et al., 2011, 2016;

**Table 4.** Plant-parasitic nematode species identified in tea plantations in Rize Province

| Species | Frequency of occurence | Feeding behaviour |
|---|---|---|
| *Coslenchus turkeyensis* | 26.30 | Ectoparasite |
| *Boleodorus thylactus* | 10.52 | Ectoparasite |
| *Filenchus filiformis* | 47.03 | Ectoparasite |
| *Geocenamus rugosus* | 42.10 | Ectoparasite |
| *Filenchus thornei* | 36.84 | Ectoparasite |
| *Helicotylenchus digonicus* | 31.57 | Ectoparasite |
| *Paratylenchus nainianus* | 5.26 | Obligate ectoparasite |
| *Pratylenchus zea* | 21.05 | Migratory endoparasite |
| *Pratylenchus penetrans* | 10.52 | Migratory endoparasite |
| *Xiphinema pachtaicum* | 5.26 | Migratory ectoparasite |
| *Trichodorus similis* | 15.78 | Migratory ectoparasite |
| *Tylenchus davainei* | 5.26 | Migratory ectoparasite |
| *Zygotylenchus gueverai* | 10.52 | Migratory endoparasite |

Saygın et al., 2023), appears to be a key factor influencing nematode community composition. Bacterivorous nematodes were more abundant in acidic soils, while certain plant-parasitic taxa tended to occur more frequently in relatively higher pH conditions. These findings are consistent with studies such as Kouser et al. (2022), which documented pH-driven shifts in the abundance of nematode trophic groups. In addition to pH, frequent fertilizer applications in Rize tea plantations likely promote conditions favorable for fast-growing, opportunistic bacterivores particularly those in lower c-p classes. Such practices, coupled with naturally acidic soils, help explain the dominance of bacterivorous nematodes observed in the present study.

The ecological indices derived from nematode community analysis varied notably among the 19 surveyed tea gardens. The MI ranged from 1.62 (garden 1) to 3.48 (garden 7), which is related to the presence of both opportunistic and persistent nematode taxa (Figure 3). Higher MI values were associated with more structured nematode communities, while lower values corresponded to environments with greater disturbance. The PPI showed moderate variability, ranging between 2.0 and 3.5, with the highest parasitic activity observed in gardens 1, 14, and 15. The Sigma Maturity Index (ΣMI) exhibited a relatively narrow range (2.0-3.25). The CI varied widely across sites, capturing a shift between bacterial and fungal decomposition pathways. Gardens 13 and 15 had the highest CI (100), gardens 1, 2, 9, and 16 recorded a CI of 0, implying a strongly bacterial-driven decomposition. The BI, a stress indicator, ranged from 1.08 (garden 7) to 28.89 (garden 1), which occur under varied stress conditions. Higher BI is associated with toxic imputs and nutrient imbalance, while the lowest value indicated minimal stress and more resilient food-web. The EI ranged from 0 to 93.33, with notably high values in gardens 3, 4, and 7, enhanced resource availability and microbial activity. The SI showed significant variation (0-98.73), with the highest values recorded in gardens 7, 13, and 6, reflecting well-structured and mature soil food webs. In these gardens higher-order nematodes (omnivores and predators) are generally common. These gardens likely benefit from consistent organic inputs, minimal disturbance, and balanced microbially-mediated nutrient cycling. In contrast, SI values of 0 in gardens 1 and 14 pointed to degraded or disturbed conditions with limited trophic complexity (Figure 3). These conditions can occur under over cultivation, heavy chemical applications or prolonged erosion of soil biological quality.

The c-p triangle of nematode c-p groups [based on Ferris et al. (2001)] (Figure 4) shows the ecological status of the surveyed tea gardens based on the distribution of life-history strategies. Gardens 3 and 4 are located near the c-p 1, where enrichment-opportunistic taxa are dominant. Gardens 1, 14, and 19 are positioned closer to the c-p 2, where stress-tolerant generalists are more prevalent. Gardens 7, 13, 15, and 16 are clustered near the c-p 3-5, which corresponds to the presence of persister taxa commonly found in stable, undisturbed systems with complex food web structures. The remaining gardens are distributed in intermediate positions across the triangle, consistent with a mix of ecological characteristics (Figure 4).

The analysis of the soil food web structure (Figure 5), based on the EI and SI as proposed by Ferris et al. (2001), revealed varying ecological conditions across the sampled tea plantations. Most samples were positioned in the upper-right quadrant, representing nematode communities typically associated with well-structured and nutrient-rich soils. Several samples were located in the lower-right quadrant, corresponding to soils with a stable food web but reduced nutrient input. A few samples, such as 1 and 19, appeared in the


**Figure 3.** Ecological indices derived from nematode communities in 19 tea gardens

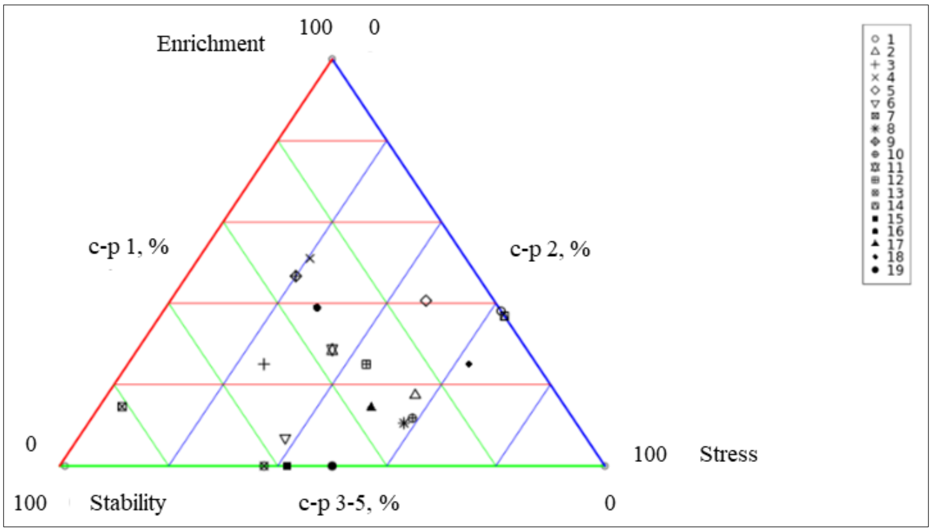


**Figure 4.** c-p triangle showing the distribution of nematode functional guilds based on c-p groups

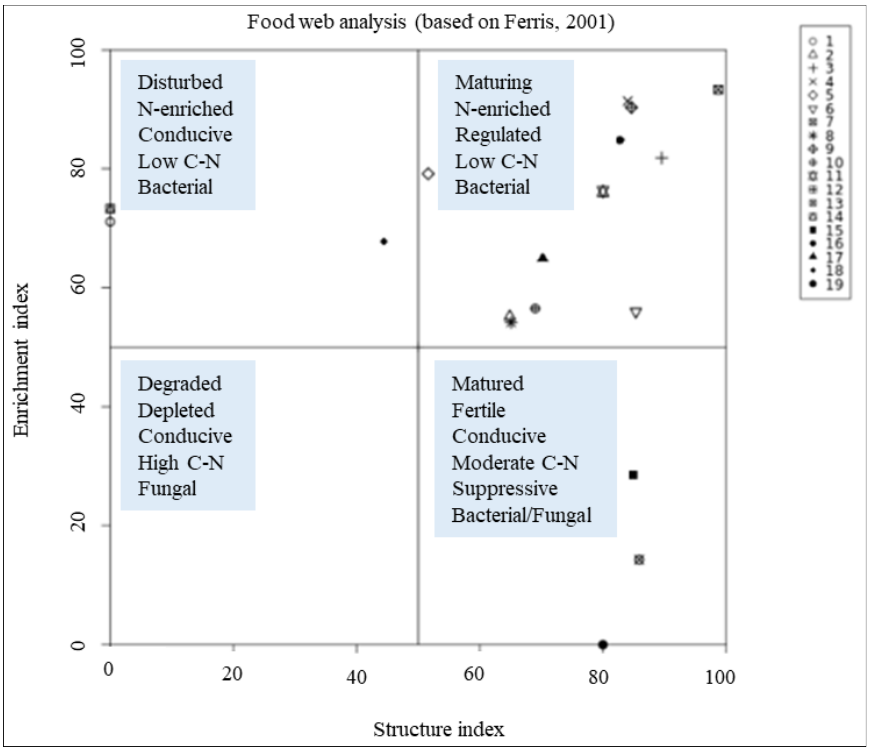


**Figure 5.** Food web analysis based on the EI and SI designed according to the Ferris et al. (2001)

lower-left quadrant, characterized by both low enrichment and weak structural complexity, reflecting disturbed conditions (Figure 5).

The combined assessment of nematode metabolic footprints and soil food web structure further clarified these ecological distinctions. In the metabolic footprint chart (Figure 6), most samples

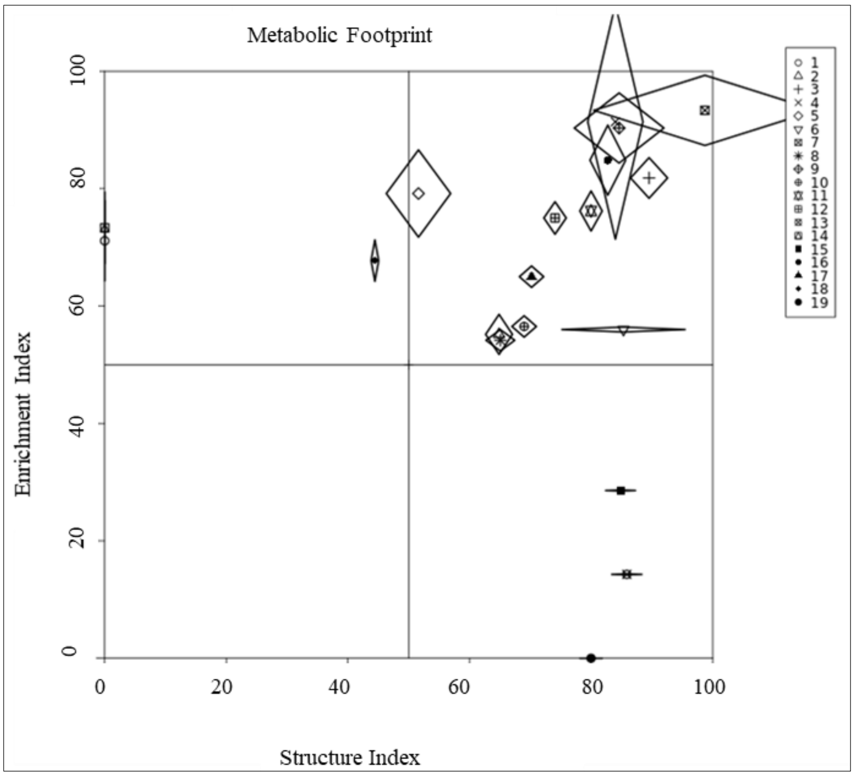


**Figure 6.** Metabolic footprint analysis of nematode communities across sampled tea plantations

clustered in the upper-right quadrant, where both EI and SI were high, accompanied by large footprint areas. These values reflect biologically active, well-structured, and nutrient-enriched environments, often dominated by bacterial communities and associated with maturing soil systems. The quadrant classification in the food web analysis aligns with these results, placing these samples within the Maturing and N-enriched zones, characterized by low carbon-to-nitrogen ratios and regulated resource dynamics. In contrast, samples such as 15, 16, and 19 appeared in the lower-right quadrant of both charts, combining high SI with low EI and smaller metabolic footprints. These samples fall into the matured category, where soils exhibit stable biological structure under lower nutrient input (Figure 6).

## 4. Conclusions

Overall, the findings reveal high spatial variability in both the functional and taxonomic diversity of nematode communities in tea plantations of Rize. The combined use of trophic structure analysis, colonizer-persister classification, and various ecological indices provided a comprehensive and detailed information on soil health and underlying biological processes. In many gardens, the dominance of stress-tolerant, fast-reproducing nematodes with low c-p values reflects disturbed soil conditions. In contrast, the presence of more sensitive, long-lived taxa with higher c-p values in some plantations points to less disturbed and more structured soil food webs. This pattern reveals the simultaneous presence of environmental stress and natural resilience in Rize's tea agroecosystems. Nematodes serve a dual function in this context: as indicators of soil disturbance and as reliable bioindicators of overall soil ecological health.

## Ethical Statement

The authors declare that ethical approval is not required for this research.

## Funding

This research received no external funding.

## Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

## Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

## References

Abolafia, J., Pena Santiago, R., 1996. Nematodes of the order Dorylaimida from Andalucia Oriental. Spain. The genus *Mesodorylaimus* Andrassy. 1959. I. Two short tailed new species. *Russian Journal of Nematology*, 4(2): 173-180.

Anderson, R.V., 1979. A supplemental key to species *Helicotylenchus* Steiner. 1945 (Nematoda: Hoplolaimidae) described since 1972 and a description of *H. oscephalus* n. sp. *Canadian Journal of Zoology*, 57(2): 337-342.

Anderson, R.V., Hooper, D.J., 1970. A neotype for *Cephalobus persegnis* Bastian. 1865. Redescription of the species. and observations on variability in taxonomic characters. *Canadian Journal of Zoology*, 48(3): 457-469.

Anonymous, 2024. Current Global Market Situation and Medium-Term Outlook. The Food and Agriculture Organisation, (https://openknowledge.fao.org/server/api/core/bitstreams/f912481a-3666-46e7-965e-30b227a19994/content), (Accessed Date: 11.03.2025).

Anonymous, 2025. TURKSTAT. Turkish Statistical Institute, (https://biruni.tuik.gov.tr/medas/?locale=tr), (Accessed Date: 17.03.2025). (In Turkish).

Banerjee, B., 1992. Botanical classification of tea. In: K.C. Willson and M.N. Clifford (Eds.), *Tea: Cultivation to Consumption*, Chapman and Hall London, pp. 25-51.

Brzeski, M.W., 1991. Review of the genus *Ditylenchus* Filipjev. 1936 (Nematoda: Anguinidae). *Revue Nematology*, 14(1): 9-59.

De Man, J.G., 1876. Onderzoekingen over vrij in de aarde levende Nematoden. *Tijdschrift Nederlandsche voor de Dierkunde Vereen*, 2: 78-196.

Ferris, H., Venette, R.C., Sipes, B.S., 2001. Nematode community structure as an indicator of soil health. In: *Soil Health and Land Use Management*, pp. 185-207.

Geraert, E., Raski, D.J., 1987. A reappraisal of Tylenchina (Nemata). *Revue Nematologia*, 10(2): 143-161.

Handoo, Z.A., Golden, A.M., 1989. A key and diagnostic compendium to the species of the genus *Pratylenchus* Filipjev. 1936 (lesion nematodes). *Journal of Nematology*, 21(2): 202-218.

Hazarika, L.K., Bhuyan, M., Hazarika, B.N., 2009. Insect pests of tea and their management. *Annual Review of Entomology*, 54: 267-284.

Huan, J., 1983. The identification of some species of root-knot nematodes (*Meloidogyne*) on tea seedlings in Zhejiang Province. *Acta Agriculture Universitatis Zhejiangensis*, 9(4): 343-359

Kepenekci, I., Akgul, H.C., 1999. Plant parasitic nematodes associated with tea (*Camellia sinensis* L.) in Rize region, Turkey. *Pakistan Journal of Nematology*, 17(2): 181-184.

Khera, S., Chaturvedi, Y., 1977. Nematodes from tea plantations of Dehra Dun, India. *Records of the Zoological Survey of India*, 72(1-4): 125-152.

Kouser, N., Nisa, R.U., Allie, K.A., Shah, A.A., 2022. Nematode diversity and community structure assessment in different vegetations of Jammu division of J & K, India. *Journal of Applied and Natural Sciences*, 14(1): 102-115.

Li, X., Liu, Q., Liu, Z., Shi, W., Yang, D., Tarasco, E., 2014. Effects of organic and other management practices on soil nematode communities in tea plantation: a case study in southern China. *Journal of Plant Nutrition and Soil Science*, 177(4): 604-612.

Mohotti, M.K., 2013. Nematode parasites and their naturally occuring biocontrol agents in tea soils of Sri Lanka. *Proceedings of the National Symposium on Soil Biodiversity*, Sri Lanka Institute of Development Administration (SLIDA), 10-11 December, Colombo, pp. 84-89.

Mukherjee, B., Dasgupta, M.K., 1982. Community analyses of plant parasitic nematodes in tea plantations, West Bengal, India. *Nematologia Mediterranea*, 10: 1-7.

Neher, D.A., Darby, B.J., 2009. General community indices that can be used for analysis of nematode assemblages. In: M. Wilson and T. Kakouli-Duarte (Eds.), *Nematodes as Environmental Indicators,* CABI, Wallingford, UK, pp. 107-123.

Orisajo, S.B., 2012. Distribution of plant parasitic nematodes associated with tea in Nigeria. *World Journal of Agricultural Sciences*, 8(5): 459-463.

Özyazıcı, M.A., Dengiz, O., Aydoğan, M., Bayraklı, B., Kesim, E., Urla, Ö., Yıldız, H., Ünal, E., 2016. Levels of basic fertility and the spatial distribution of agricultural soils in Central and Eastern Black Sea Region. *Anadolu Journal of Agricultural Sciences*, 31(1): 136-148. (In Turkish).

Özyazıcı, M.A., Özyazıcı, G., Dengiz, O., 2011. Determination of micronutrients in tea plantations in the Eastern Black Sea Region, Turkey. *African Journal of Agricultural Research*, 6(22): 5174-5180.

Palomares-Rius, J.E., León-Ropero, G., Clavero-Camacho, I., Archidona-Yuste, A., Cantalapiedra-Navarrete, C., Castillo, P., 2022. A new interactive web-based polytomous key for species identification of pin nematodes of the genus *Paratylenchus* Micoletzky, 1922 (Nematoda: Paratylenchinae) with the use of ribosomal and mitochondrial genes. *Journal of Zoological Systematics and Evolutionary Research*, Article ID 6216266.

Paul, S., Ahmed, M., Mamun, M., Alam, M., 2018. Diversity of insect mite and nematode species in tea ecosystem of Bangladesh. *Journal of Biodiversity Conservation and Bioresource Management*, 3(1): 31-44.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, 13: 131-144.

Saygın, F., Şavşatlı, Y., Dengiz, O., Yazıcı, K., Namlı, A., Karataş, A., Demirkaya, S., 2023. Soil quality assessment based on hybrid computational approach with spatial multi-criteria analysis and geographical information system for sustainable tea cultivation. *The Journal of Agricultural Science*, 161(2): 187-204.

Scholze, V.S., Sudhaus, W., 2011. A pictorial key to current genus groups of 'Rhabditidae'. *Journal of Nematode Morphology and Systematics*, 14(2): 105-112.

Siddiqi, M.R., 2000. Tylenchida: Parasites of Plants and Insects. CABI International, Wallingford, UK.

Sieriebriennikov, B., Ferris, H., de Goede, R. G. M., 2014. NINJA: An automated calculation system for nematode-based biological monitoring. *European Journal of Soil Biology*, 61: 90 -93.

Taher, I.E., Ami, S.N., Haleem, R.A., Shareef, B., 2017. First record of mycetophagous nematode *Aphelenchus avenae* in Iraq with description and testing their propagatıon on different fungus culture. *Bulletin of The Iraq Natural History Museum*, 14(3): 251-259.

Yeates, G.W., Ferris, H., Moens, T., Van Der Putten, W.H., 2009. The role of nematodes in ecosystems. In: M.J. Wilson and T. Khakouli-Duarte (Eds.), *Nematodes as Environmental Indicators*, CABI, Cambridge, Massachusetts, pp. 1-44.

Yurteri, E., Ozcan, A., Seyis, F., 2019. Tea (*Camellia sinensis*) cultivation and breeding in Turkey: Past and present status. *Ekin Journal of Crop Breeding and Genetics*, 5(2): 111-119.

**CITATION:** Sivri, N., Öztürk, L., 2025. Assessment of Soil Health Using Nematode Communities in Tea [*Camellia sinensis* (L.) O. Kuntze] Plantations of Rize, Türkiye. *Turkish Journal of Agricultural Research*, 12(2): 185-194.