



Species composition and structure of the phytoneamatode complex of soybean in the Right-Bank Forest-Steppe of Ukraine

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Abstract. The aim of the study was to determine the species composition as well as the taxonomic and ecological structure of the phytoneamatode complex associated with soybean under conditions of the Right-Bank Forest-Steppe of Ukraine. The study employed field route surveys, laboratory methods for nematode extraction from soil and root systems (Baermann funnel technique and sieving method), morphological and morphometric identification using light microscopy, as well as structural-ecological analysis of communities and methods of variation statistics. It was established that the nematode complex of the soybean rhizosphere comprises 26 species belonging to 17 genera, 10 families, 5 orders, and 2 classes, indicating a high taxonomic diversity of soil biota in the agrocenosis. The class Chromadorea dominated (over 80% of the total structure), determining the functional orientation of the community under intensive agricultural use. The order Tylenchida was the most abundant, forming the main share of the phytoparasitic block and including economically important species such as *Pratylenchus penetrans*, *Tylenchorhynchus dubius*, *Helicotylenchus dihystra*, and *Paratylenchus nanus*. Their dominance indicated the formation of a stable invasion potential in the soybean rhizosphere and the presence of critical phytosanitary pressure. At the same time, a significant proportion of saprobiotic and bacteriotrophic nematodes (Rhabditida and Cephalobidae) indicated intensive processes of organic matter mineralization and active functioning of the soil microbial component. The combination of a high proportion of phytoparasitic and decomposer forms creates a functionally heterogeneous community structure, reflecting simultaneous processes of ecological stress and biological compensation in the agroecosystem. Structural analysis revealed an intermediate level of ecological stability of the system, characteristic of intensively used agricultural lands with periodic disturbance of soil structure and simplification of trophic relationships. The results obtained can be used for bioindication assessment of soil condition and for the development of ecologically oriented monitoring systems and protection of soybean crops against phytonematodes

Keywords: species composition; taxonomic structure; agrocenoses; *Pratylenchus penetrans*; *Tylenchorhynchus dubius*; soil bioindication

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INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the most strategically important leguminous crops in both global and regional agriculture, combining high food, feed, and agroecological value. Its importance is determined not only by its high protein and vegetable oil content, but also by its ability to fix atmospheric nitrogen symbiotically, which significantly affects soil nutrient balance and reduces the need for mineral fertilisers. However, under current trends of global warming, soil degradation, and intensification of agricultural production, achieving consistently high soybean yields is impossible without effective control of harmful organisms, among which phytoneamatodes are among the most problematic. Recent studies indicate that plant-parasitic nematodes cause significant yield losses in many agricultural crops. A. Pulavarty *et al.* (2021) noted that phytoneamatodes have global importance as biotic stressors capable of substantially reducing crop productivity across different climatic zones. At the same time, the authors emphasised that damage at the initial stages of field infestation may not be visually apparent, complicating their diagnosis and, consequently, phytosanitary control. F.A. Adamu *et al.* (2024) demonstrated that phytoneamatodes significantly affect the physiological condition of soybean plants by disrupting water balance, reducing nutrient uptake efficiency, and causing secondary infections due to root tissue damage. According to F.A. Adamu *et al.*, even at relatively low population densities, nematodes can lead to a considerable reduction in plant biomass and productivity. Representatives of the genus *Pratylenchus* play a particularly important role in modern nematology. S.H. Abdel-Baset *et al.* (2025) reported that *Pratylenchus* spp. are among the most damaging nematodes of soybean, capable of penetrating root tissues and causing necrotic lesions, which disrupt water and nutrient transport. These nematodes form stable soil populations and can survive for extended periods even in the absence of typical host plants.

In addition, cyst-forming nematodes and other parasitic groups play an important role in shaping the phytosanitary status of agroecosystems, with their distribution largely depending on agronomic practices and land-use structure. In this context, the findings of A. Babych *et al.* (2024)

are of particular importance, demonstrating that populations of cyst-forming nematodes in field agroecosystems are characterised by high stability and the ability to persist in anabiosis for many years in the absence of suitable host plants. The authors found that key factors regulating their abundance include scientifically grounded anti-nematode crop rotations and the level of saturation of agroecosystems with susceptible crops. Furthermore, it was emphasised that disruption of agronomic balance promotes the accumulation of invasion potential of cyst-forming nematodes, creating long-term risks for crop productivity. These findings complement current understanding of the spatiotemporal dynamics of plant-parasitic nematodes and confirm the need to consider their population resilience when developing integrated pest management systems. A separate line of research concerns the influence of agricultural practices on the structure of nematode communities. H.-W. Wang *et al.* (2022) found that intensive farming systems, particularly deep mechanical soil tillage and simplified crop rotations, lead to reduced trophic diversity of nematodes and an increased proportion of plant-parasitic forms. Such changes indicate disruption of trophic links and reduced ecological stability of agroecosystems. E.M. Furmanczyk *et al.* (2025) showed that nematode communities are sensitive indicators of land-use change. They demonstrated that monoculture systems, particularly long-term soybean cultivation without proper crop rotation, promote the accumulation of plant-parasitic nematodes and reduce the functional diversity of soil biota, negatively affecting agroecosystem stability.

The article by U. Shrestha *et al.* (2020) summarised modern approaches to the use of nematodes as bioindicators of soil health, emphasising that the structure of nematode communities is an integral indicator of soil ecological condition. U. Shrestha *et al.* argued that the ratio between trophic groups allows assessment of both anthropogenic pressure and the level of functional maturity of ecosystems. J. Kim *et al.* (2024) drawn attention to the genetic variability of plant-parasitic nematodes, which provides them with high adaptability to climatic and technological conditions. The authors outlined that this characteristic complicates the effective control of nematodes

under field conditions and highlights the importance of taking these features into account when developing integrated plant protection systems. Recent syntheses by S. Lazarova *et al.* (2021) indicated that nematodes are both important regulators of soil processes and significant phytopathogens that can determine the economic efficiency of crop production. The authors emphasised the need for a comprehensive approach to evaluating their role in soil ecosystems.

Thus, the current scientific literature demonstrates the high ecological and economic significance of phytoneamatodes in soybean agrocenoses. They are a relevant component of soil systems, while simultaneously acting as a major limiting factor for crop productivity. Despite certain advances in understanding their biology and ecology, questions regarding species structure, dominance of individual taxa, and the functional organisation of nematode communities in soybean agrocenoses of the Right-Bank Forest-Steppe of Ukraine remain insufficiently studied, highlighting the relevance of this research. The aim of the study was to investigate the diversity, taxonomic composition, and ecological structure of the phytoneamatode complex associated with soybean in the Right-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The study was conducted during 2023–2025 under stationary field conditions at the Agronomic Research Station of the National University of Life and Environmental Sciences of Ukraine, located in the Right-Bank Forest-Steppe zone of Ukraine. The soils of the experimental plots were typical low-humus chernozems with a medium loamy texture, characterised by high natural fertility and favourable physicochemical properties for soybean cultivation. The object of the study was the regulatory mechanisms of phytoneamatodes in the soybean (*Glycine max* (L.) Merr.) rhizosphere. The subject of the study included species composition, taxonomic structure, and the dominance level of individual taxa within the agrocenosis. Soil and plant samples were collected throughout the soybean growing season (emergence, budding, and pod-filling stages) following the standard route survey methodology. Each composite sample consisted of 10–15 subsamples collected using the “envelope” method within an area of

up to 1 hectare. The total weight of a composite sample ranged from 500 to 1,000 g. Root samples were collected simultaneously with soil samples and transported to the laboratory in sealed containers to prevent desiccation. Nematodes were extracted from soil using a modified Baermann funnel technique with an exposure time of 24–48 hours. To improve extraction efficiency, a sieving method was also applied using a set of sieves with mesh sizes of 1.0, 0.5 and 0.25 mm. Nematodes from plant material were extracted by macerating root tissues followed by incubation in water using Baermann funnels (Hooper *et al.*, 2005). For fixation, nematodes were preserved in a 4% formalin solution or TAF (triethanolamine-formalin). Permanent slides were prepared using the J.W. Seinhorst (1959) method (standard glycerine dehydration method).

Nematode identification was carried out based on morphological and morphometric characteristics using a light microscope at magnifications ranging from $\times 100$ to $\times 1,000$. Species identification was carried out using taxonomic keys and identification manuals (Mai, 2018), while modern systematic criteria described by T.J. Jones *et al.* (2013) were applied to ensure taxonomic consistency. For each sample, species composition, abundance, and taxonomic affiliation were determined. The taxonomic structure of nematode communities was analysed at the levels of class, order, family, genus, and species. Community structure was assessed using indices of species diversity and relative abundance (%). Species dominance was determined according to the scale commonly used in soil zoology: dominant species (>10%), subdominant species (1–10%), and rare species (<1%). The ecological structure of the nematode complex was evaluated based on trophic classification by G.W. Yeates *et al.* (1993), categorising species into phytoparasitic, bacterivorous, and fungivorous groups. This approach allowed determination of the functional role of the community within the agrocenosis. All experimental procedures, including plant sampling, were conducted in accordance with the principles of the Convention on Biological Diversity (2010). The mathematical processing of the obtained results was performed using methods of variation statistics. Mean values, standard deviations, and relative indicators were calculated. To assess the significance of differences between

samples, both parametric and non-parametric tests were applied, including the Student's t-test for independent samples and the χ^2 test for the analysis of frequency distributions, depending on the nature of data distribution. The level of statistical significance was set at $p < 0.05$, with the corresponding p-values calculated for each test.

Graphical models of the research results were developed using Microsoft Excel.

RESULTS AND DISCUSSION

The taxonomic analysis of the nematode complex in soybean agrocenoses indicates its considerable diversity and hierarchical organisation (Fig. 1).

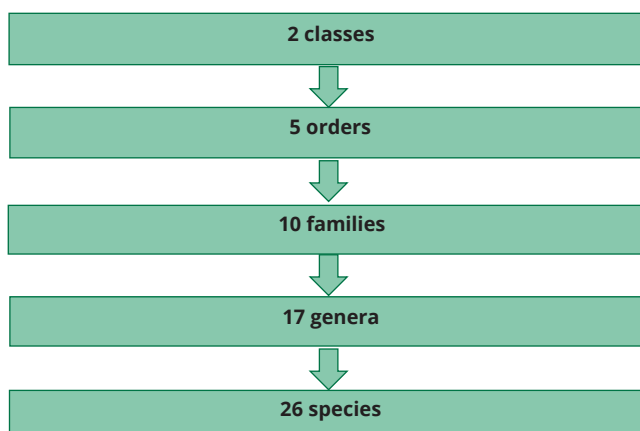


Figure 1. Taxonomic structure of the phytoneamatode complex in soybean agrocenoses

Source: developed by the authors

The highest number of nematode species belongs to the class Chromadorea, whereas the class Enoplea is represented by a smaller number of taxa. The dominance of particular families and genera of plant-parasitic and saprobiotic nematodes reflects the ecological heterogeneity of the soybean agrocenosis. The established taxonomic

structure characterises the soybean agrocenosis as a relatively stable ecosystem with a high level of functional differentiation of nematode fauna. A total of 26 species were identified within the community, belonging to 17 genera, 10 families, 5 superfamilies, and 5 orders, grouped into 2 classes – Enoplea and Chromadorea (Table 1).

Table 1. Systematic position of nematode species in the soybean rhizosphere

Class	Order	Superfamily	Family	Subfamily	Genus	Species
Enoplea	Araeolaimida de Coninck et Sch. Stekhoven, 1933	-	Plectidae Oerley, 1880	-	<i>Plectus</i>	<i>Plectus elongatus</i> Bastian, 1865
Enoplea	Enoplida Chitwood, 1933	-	Alaimidae Micoletzky, 1922	-	<i>Alaimus</i>	<i>Alaimus</i> <i>primitivus</i> de Man, 1880
Enoplea	Dorylaimida Pearse, 1936	Dorylaimoidea de Man, 1876; Thorne, 1934	Dorylaimidae de Man, 1876	Mesodorylaiminae Andrassy, 1959	<i>Mesodorylaimus</i>	<i>Mesodorylaimus</i> <i>bastiani</i> (Butschli, 1873) Andrassy, 1959
Chromadorea	Rhabditida Chitwood, 1933	Rhabditoidea Oerley, 1880; Travassos, 1920	Rhabditidae Oerley, 1880	Rhabditinae Micoletzky, 1922	<i>Pelodera</i>	<i>Pelodera teres</i> Schneider, 1866

Table 1. Continued

Class	Order	Superfamily	Family	Subfamily	Genus	Species
Chromadorea	Rhabditida Chitwood, 1933	Rhabditoidea Oerley, 1880; Travassos, 1920	Rhabditidae Oerley, 1880	Rhabditinae Micoletzky, 1922	<i>Mesorhabditis</i>	<i>Mesorhabditis monohystera</i> (Butschli, 1873) Dougherty, 1955
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Cephalobinae Filipjev, 1934	<i>Cephalobus</i>	<i>Cephalobus persegnis</i> Bastian, 1865
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Cephalobinae Filipjev, 1934	<i>Eucephalobus</i>	<i>Eucephalobus oxiuroides</i> (de Man, 1876) Steiner, 1936
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Cephalobinae Filipjev, 1934	<i>Eucephalobus</i>	<i>Eucephalobus mucronatus</i> (Kosłowska, Rogińska- Wasilewska, 1963) Andrassy, 1967
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Acrobelinae Thorne, 1937	<i>Acrobeloides</i>	<i>Acrobeloides butschlii</i> (de Man, 1884) Steiner & Buhrer, 1933
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Acrobelinae Thorne, 1937	<i>Acrobeles</i>	<i>Acrobeles ciliatus</i> von Linstow, 1877
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Acrobelinae Thorne, 1937	<i>Chiloplacus</i>	<i>Chiloplacus symmetricus</i> (Thorne, 1925) Thorne, 1937
Chromadorea	Rhabditida Chitwood, 1933	Cephaloidea Paramonov, 1952	Cephalobidae (Filipjev, 1934) Chitwood et Chitwood, 1934	Acrobelinae Thorne, 1937	<i>Cervidellus</i>	<i>Cervidellus devimucronatus</i> Sumencova, 1964
Chromadorea	Rhabditida Chitwood, 1933	-	Panagrolaimidae Thorne, 1937; Paramonov, 1956	Panagrolaiminae Thorne, 1937	<i>Panagrolaimus</i>	<i>Panagrolaimus rigidus</i> (Schneider, 1866) Thorne, 1937
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Aphelenchoidea Fuchs, 1970; Thorne, 1949	Aphelenchidae Bastian, 1865	-	<i>Aphelenchus</i>	<i>Aphelenchus avenae</i> Bastian, 1865
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Aphelenchoidea Fuchs, 1970; Thorne, 1949	Aphelenchoididae Skarbilovich, 1947; Paramonov, 1953	Aphelenchoidinae Skarbilovich, 1947	<i>Aphelenchoides</i>	<i>Aphelenchoides asterocaudatus</i> Das, 1960

Table 1. Continued

Class	Order	Superfamily	Family	Subfamily	Genus	Species
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Aphelenchoidea Fuchs, 1970; Thorne, 1949	Aphelenchoididae Skarbilovich, 1947; Paramonov, 1953	Aphelenchoidinae Skarbilovich, 1947	<i>Aphelenchoides</i>	<i>Aphelenchoides bicaudatus</i> (Imamura, 1931) Filipjev & Sch. Stekhoven, 1941
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Tylenchoidea Filipjev, 1934; Chitwood & Chitwood, 1947	Tylenchidae Oerley, 1880	Tylenchinae Filipjev, 1934	<i>Aglenchus</i>	<i>Aglenchus agricola</i> (de Man, 1884) Andrassy, 1954
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Tylenchoidea Filipjev, 1934; Chitwood & Chitwood, 1947	Tylenchidae Oerley, 1880	Tylenchinae Filipjev, 1934	<i>Aglenchus</i>	<i>Aglenchus costatus</i> de Man, 1921
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Filipjev, 1934; Paramonov, 1967	Tylenchorhynchidae (Fliava, 1964) Golden, 1971	Tylenchorhynchinae Fliava, 1964	<i>Tylenchorhynchus</i>	<i>Tylenchorhynchus dubius</i> (Butschli, 1873) Filipjev, 1936
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Filipjev, 1934; Paramonov, 1967	Pratylenchidae Thorne, 1949; Siddigi, 1963	Pratylenchinae Thorne, 1949	<i>Pratylenchus</i>	<i>Pratylenchus penetrans</i> (Cobb, 1917) Filipjev & Schuurmans Stekhoven, 1941
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Filipjev, 1934; Paramonov, 1967	Pratylenchidae Thorne, 1949; Siddigi, 1963	Pratylenchinae Thorne, 1949	<i>Pratylenchus</i>	<i>Pratylenchus pratensis</i> (de Man, 1880) Filipjev, 1936
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Filipjev, 1941; Wieser, 1953	Hoplolaimidae (Filipjev, 1941) Wieser, 1953	Rotylenchoidinae Whitehead, 1958	<i>Helicotylenchus</i>	<i>Helicotylenchus dihystera</i> (Cobb, 1893) Sher, 1961
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Thorne, 1949	Paratylenchidae Thorne, 1949; Raski, 1962	-	<i>Paratylenchus</i>	<i>Paratylenchus nanus</i> (Cobb, 1923) Brzeski, 1936
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Jairajpuri, 1965	Qudsianematidae Jairajpuri, 1965; Siddigi, 1969	Qudsianematinae Jairajpuri, 1965	<i>Eudorilaimus</i>	<i>Eudorilaimus obtusicaundatus</i> (Bastian, 1865) Andrassy, 1959
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Jairajpuri, 1965	Qudsianematidae Jairajpuri, 1965; Siddigi, 1969	Qudsianematinae Jairajpuri, 1965	<i>Eudorilaimus</i>	<i>Eudorilaimus monohystera</i> (Bastian, 1865) Andrassy, 1959

Table 1. Continued

Class	Order	Superfamily	Family	Subfamily	Genus	Species
Chromadorea	Tylenchida Filipjev, 1934; Thorne, 1949	Hoplolaimoidea Jairajpuri, 1965	Qudsianematidae Jairajpuri, 1965; Siddigi, 1969	Qudsianematinae Jairajpuri, 1965	<i>Eudorilaimus</i>	<i>Eudorilaimus projectus</i> (de Man, 1880) Andrassy, 1959

Note: domain: *Eukaryota*; Kingdom: *Animalia*; Subkingdom: *Eumetazoa*; Superphylum: *Bilateria*; Clade: *Protostomia*; Phylum: *Nematoda*

Source: developed by the authors

The greatest species diversity was characteristic of the order Tylenchida, which includes both plant-parasitic nematodes (in particular representatives of the genera *Pratylenchus*, *Tylenchorhynchus*, and *Helicotylenchus*) and facultatively saprobiontic forms that play an important role in soil processes. Alongside them, bacteriophagous and saprobiontic nematodes were also represented (including representatives of Rhabditida and Cephalobidae), as well as more primitive dorylaimid species of the class Enoplea, indicating the coexistence of different ecological groups ranging from soil decomposers to

specialised plant-parasitic species. In general, the community structure indicates a complex functional organisation of the nematode complex in the soybean agrocenosis and its dependence on trophic conditions. In the taxonomic structure, the class Chromadorea was dominant, comprising 22 species (84.6%). Representatives of this class form the basis of soil nematode communities in agrocenoses and include both saprobiontic and plant-parasitic forms. The class Enoplea was represented by only 4 species (15.4%), indicating its subordinate role in the formation of the studied complex (Fig. 2).

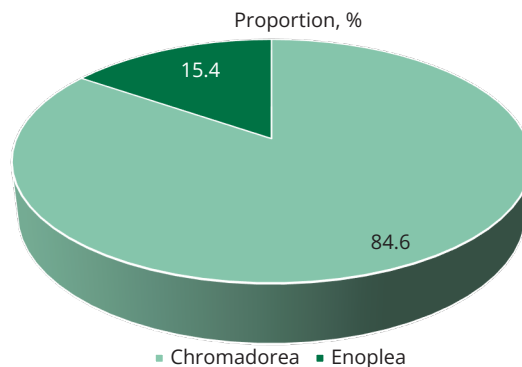


Figure 2. Structure of the nematode complex (by classes)

Source: developed by the authors

The class Enoplea is represented by only 4 species (15.4%), indicating its subordinate role in the formation of the studied complex. The most abundant order is Tylenchida, which includes 14 species (53.8%) and plays a key role in shaping the phytoparasitic component of the nematode community. It includes economically important species such as *Tylenchorhynchus dubius*,

Pratylenchus penetrans, *Pratylenchus pratensis*, *Helicotylenchus dihystrera*, and *Paratylenchus nanus*. A subdominant position is occupied by the order Rhabditida with 10 species (38.5%), represented mainly by bacteriotrophic and saprobiontic forms (*Cephalobus*, *Acrobeloides*, *Panagrolaimus*, etc.), which play an important role in the mineralisation of organic matter (Fig. 3).

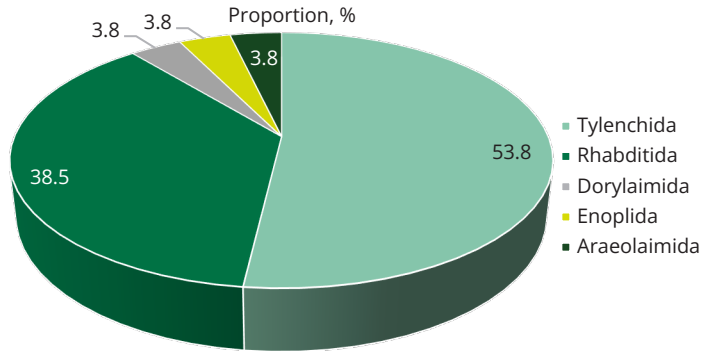


Figure 3. Structure of the nematode complex (by orders)

Note: other orders are represented insignificantly: Dorylaimida – 1 species; Enoplida – 1 species; Araeolaimida – 1 species

Source: developed by the authors

Thus, the structure is characterised by a pronounced polydominant-monodominant pattern with the absolute predominance of Tylenchida. Such a structure of the nematode community can be explained by the agrotechnical conditions associated with intensive agricultural use of the soil, particularly the cultivation of crops in monoculture or short-rotation crop systems, which promote the accumulation of plant-parasitic species of the order Tylenchida. An additional factor is the systematic application of organic

fertilisers, which supports high populations of bacteriotrophic forms (Rhabditida) but does not limit the development of plant-parasitic nematodes. The highest species richness is observed in the families *Cephalobidae*, *Rhabditidae*, *Aphelenchoididae*, *Tylenchidae*, and *Pratylenchidae*. A considerable proportion is also represented by *Qudsianematidae* and *Panagrolaimidae*. This indicates the coexistence of both saprobiontic and phytoparasitic elements within the structure of the complex (Fig. 4).

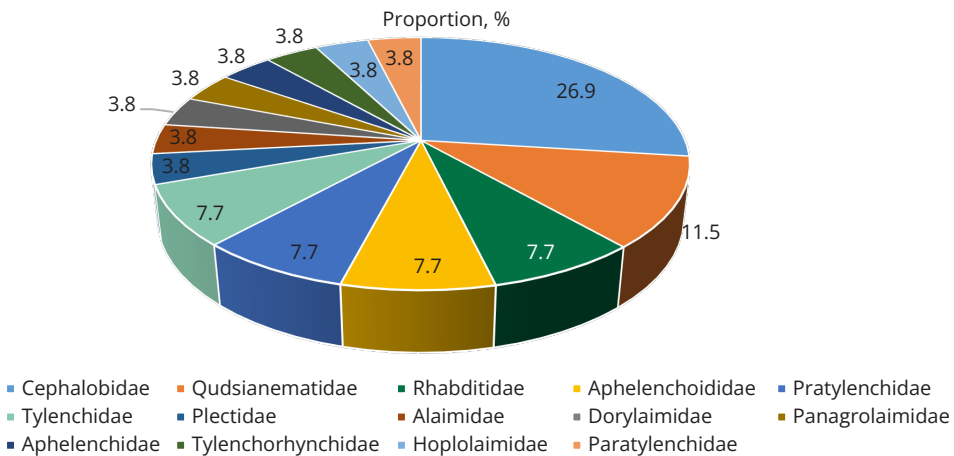


Figure 4. Structure of the nematode complex (by families)

Source: developed by the authors

The generic structure of the nematode complex is characterised by a high level of diversity

(20 genera) and the absence of clearly expressed dominant genera. The leading position is occupied

by the genus *Eudorilaimus* (11.5%) and a group of subdominants (*Eucephalobus*, *Pratylenchus*, *Aglenchus*, *Aphelenchoides* – 7.7% each). The lowest species richness is observed in genera represented by a single species (3.8% each), which belong to the group of decomposers, including: *Plectus*, *Alaimus*, *Mesodorylaimus*, *Pelodera*, *Mesorhabditis*,

Cephalobus, *Acrobeloides*, *Acrobeles*, *Chiloplacus*, *Cervidellus*, *Panagrolaimus*, *Aphelenchus*, *Tylenchorhynchus*, *Helicotylenchus*, and *Paratylenchus*. Their combined share constitutes 57.7% of the total number of genera, indicating high taxonomic diversity and a relatively even structure of the nematode community (Fig. 5).

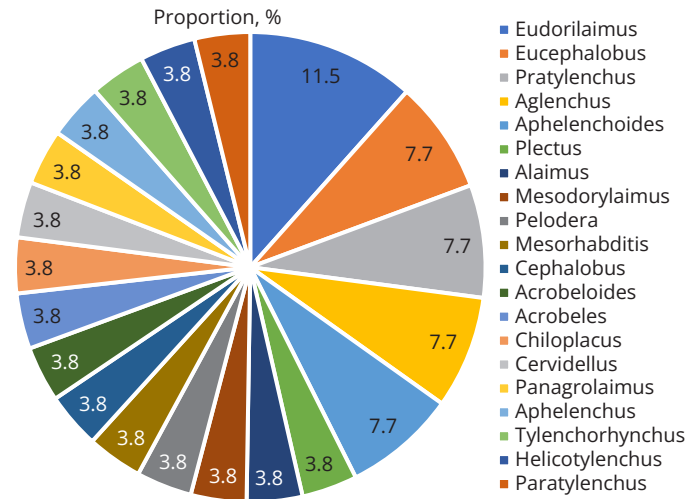


Figure 5. Structure of the nematode complex (by genera)

Source: developed by the authors

The diagram indicates a relatively uniform generic structure of the nematode complex without pronounced dominance of individual taxa. The genus *Eudorylaimus* constituted the largest proportion (11.5%), whereas the genera *Eucephalobus*, *Pratylenchus*, *Aglenchus*, and *Aphelenchoides* each accounted for 7.7%. The remaining genera were represented by lower proportions (3.8%), indicating a moderately balanced taxonomic diversity. Based on the conducted analysis, phytoneamatodes in soybean agrocenoses were categorised into three dominance groups. Based on the conducted analysis, phytoneamatodes in soybean agrocenoses were categorised into three dominance groups. The dominant species, which

are the most abundant and ecologically influential in the agrocenosis, include *Pratylenchus penetrans* (Pratylenchidae, Tylenchida/Chromadorea) and *Tylenchorhynchus dubius* (Tylenchorhynchidae, Tylenchida/Chromadorea). The subdominant species, although less abundant, are locally capable of affecting plant health, and these include *Pratylenchus pratensis*, *Helicotylenchus dihystera*, *Paratylenchus nanus*, *Aphelenchoides bicaudatus*, and *Aphelenchus avenae*. The rare species, which are mostly saprophytic or poorly studied, include *Eudorylaimus*, *Aglenchus*, *Plectus*, *Alaimus*, *Mesodorylaimus*, *Pelodera*, *Mesorhabditis*, *Cephalobus*, *Eucephalobus*, *Acrobeloides*, *Acrobeles*, *Chiloplacus*, *Cervidellus*, and *Panagrolaimus* (Table 2).

Table 2. Dominance of phytoneamatodes

Status	Species	Genus	Order/Class
Dominant	<i>Pratylenchus penetrans</i>	Pratylenchus	Tylenchida/Chromadorea
Dominant	<i>Tylenchorhynchus dubius</i>	Tylenchorhynchus	Tylenchida/Chromadorea
Subdominant	<i>Pratylenchus pratensis</i>	Pratylenchus	Tylenchida/Chromadorea
Subdominant	<i>Helicotylenchus dihystera</i>	Helicotylenchus	Tylenchida/Chromadorea

Table 2. Continued

Status	Species	Genus	Order/Class
Subdominant	<i>Paratylenchus nanus</i>	Paratylenchus	Tylenchida/Chromadorea
Subdominant	<i>Aphelenchoides bicaudatus</i>	Aphelenchoides	Tylenchida/Chromadorea
Subdominant	<i>Aphelenchus avenae</i>	Aphelenchus	Tylenchida/Chromadorea
Rare	<i>Eudorilaimus obtusicaundatus</i>	Eudorilaimus	Tylenchida/Chromadorea
Rare	<i>Eudorilaimus monohystera</i>	Eudorilaimus	Tylenchida/Chromadorea
Rare	<i>Eudorilaimus projectus</i>	Eudorilaimus	Tylenchida/Chromadorea
Rare	<i>Aglenchus agricola</i>	Aglenchus	Tylenchida/Chromadorea
Rare	<i>Aglenchus costatus</i>	Aglenchus	Tylenchida/Chromadorea
Rare	<i>Plectus elongatus</i>	Plectus	Araeolaimida/Enoplea
Rare	<i>Alaimus primitivus</i>	Alaimus	Enoplida/Enoplea
Rare	<i>Mesodorylaimus bastiani</i>	Mesodorylaimus	Dorylaimida/Enoplea
Rare	<i>Pelodera teres</i>	Pelodera	Rhabditida/Chromadorea
Rare	<i>Mesorhabditis monohystera</i>	Mesorhabditis	Rhabditida/Chromadorea
Rare	<i>Cephalobus persegnis</i>	Cephalobus	Rhabditida/Chromadorea
Rare	<i>Eucephalobus oxiuroides</i>	Eucephalobus	Rhabditida/Chromadorea
Rare	<i>Eucephalobus mucronatus</i>	Eucephalobus	Rhabditida/Chromadorea
Rare	<i>Acrobeloides butschlii</i>	Acrobeloides	Rhabditida/Chromadorea
Rare	<i>Acrobeles ciliatus</i>	Acrobeles	Rhabditida/Chromadorea
Rare	<i>Chiloplacus symmetricus</i>	Chiloplacus	Rhabditida/Chromadorea
Rare	<i>Cervidellus devimucronatus</i>	Cervidellus	Rhabditida/Chromadorea
Rare	<i>Panagrolaimus rigidus</i>	Panagrolaimus	Rhabditida/Chromadorea

Source: developed by the authors

Table 2 reflects a clearly expressed structural differentiation of the phytoneamatode complex in soybean agrocenoses along the dominance gradient. The dominant block is represented by two species of the genera *Paratylenchus* and *Tylenchorhynchus*, belonging to the order Tylenchida, and forms the main plant-parasitic core of the community, determining the potential level of damage to the soybean root system. The subdominant group is more diverse and includes both migratory endoparasites (*Paratylenchus pratensis*) and epiphytic as well as semi-endoparasitic forms (*Helicotylenchus*, *Paratylenchus*), together with fungimycotrophic and mixotrophic species (*Aphelenchoides*, *Aphelenchus*), indicating an increased complexity of the trophic structure of the nematode complex. Rare species are represented mainly by saprobiontic and soil-dwelling forms of different ecological groups (bacteriotrophs, fungivores, and primitive

dorylaimids), which characterise the general condition of the soil biocenosis and the level of its biodiversity. Thus, the community structure shows a pronounced shift toward a plant-parasitic assemblage of the order Tylenchida while maintaining a significant saprotrophic component, which overall reflects the agrocenotic nature of the environment and its anthropogenic transformation. Overall, the taxonomic structure of the nematode complex is characterised by a high level of species and generic diversity, the dominance of representatives of the class Chromadorea, the predominance of the order Tylenchida, which forms the basis of the phytoparasitic complex, and a significant proportion of saprobiontic forms (Rhabditida) that ensure the functioning of the soil ecosystem. The ratio of taxa from different trophic groups indicates ecological balance and functional completeness of the nematode community (Table 3).

Table 3. Dominance by families and orders

Order/Class	Family	Number of species	Status
Tylenchida/Chromadorea	Pratylenchidae	2	Dominant/Subdominant
Tylenchida/Chromadorea	Tylenchorhynchidae	1	Dominant
Tylenchida/Chromadorea	Hoplolaimidae	1	Subdominant

Table 3. Continued

Order/Class	Family	Number of species	Status
Tylenchida/Chromadorea	Paratylenchidae	1	Subdominant
Tylenchida/Chromadorea	Qudsianematidae	3	Rare
Tylenchida/Chromadorea	Tylenchidae	2	Rare
Tylenchida/Chromadorea	Aphelenchoididae	2	Subdominant
Tylenchida/Chromadorea	Aphelenchidae	1	Subdominant
Rhabditida/Chromadorea	Rhabditidae	2	Rare
Rhabditida/Chromadorea	Cephalobidae	7	Rare
Rhabditida/Chromadorea	Panagrolaimidae	1	Rare
Araeolaimida/Enoplea	Plectidae	1	Rare
Enoplida/Enoplea	Alaimidae	1	Rare
Dorylaimida/Enoplea	Dorylaimidae	1	Rare

Source: developed by the authors

The results presented in the Table 3 demonstrate not only the taxonomic structure of the nematode complex but also its functional organisation within the soybean agroecosystem. The predominance of the order *Tylenchida* (*Chromadorea*) indicates the dominance of plant-parasitic forms that directly affect the phytosanitary condition of the crop. In particular, migratory endoparasites of the family *Pratylenchidae* are among the factors negatively influencing soybean productivity through damage to the root system, disruption of water and nutrient balance in plants, and the creation of secondary infection sites for pathogens. Species of the family *Tylenchorhynchidae* form the ectoparasitic component that suppresses root growth and reduces the overall vitality of plants, whereas representatives of the families *Hoplolaimidae* and *Paratylenchidae* are of considerable phytosanitary importance, especially in short-rotation crop systems with a high proportion of related crops. Nematodes of the families *Aphelenchoididae* and *Aphelenchidae*, although mainly belonging to fungimycotrophic forms, may act as indirect regulators of the soil mycobiota, influencing the balance between beneficial and pathogenic fungi, which is also reflected in the condition of the rhizosphere. At the same time, the high representation of the families *Rhabditidae*, *Cephalobidae*, and *Panagrolaimidae* within *Rhabditida* indicates intensive processes of organic matter decomposition and mineralisation, which constitutes a positive factor for the functioning of the soil ecosystem, since these groups participate in the transformation of organic matter and nutrient cycling. Representatives of *Enoplea* (*Plectidae*,

Alaimidae, *Dorylaimidae*), despite their relatively low abundance, perform an important indicator function by reflecting the level of stability of the soil environment. Their presence indicates a certain degree of ecological diversity and the partial preservation of natural mechanisms regulating the community. Thus, the structure presented in the table is characterised by a combination of a pronounced plant-parasitic complex (*Tylenchida*) and a well-developed saprobiontic block (*Rhabditida*), which together determine both the negative impact on soybean productivity through parasitic pressure and the maintenance of fundamental soil biocenosis processes through active mineralisation of organic matter.

The conducted study demonstrated that the nematode complex of soybean agroecosystems under the conditions of the Right-Bank Forest-Steppe of Ukraine is characterised by high taxonomic richness and clear functional differentiation, which is typical of intensively exploited agricultural landscapes of the temperate zone. Similar patterns of structural organisation of soil communities under different land-use systems were reported by E.M. Furmanczyk *et al.* (2025), who showed that the type of agroecosystem is a key factor determining both species diversity and the dominance of particular trophic groups of nematodes. The authors emphasised that intensive farming systems contribute to a reduction in community complexity and an increase in the role of plant-parasitic forms. The general concept of using nematodes as indicators of soil condition was comprehensively discussed by J.L. Garland *et al.* (2010), who demonstrated that the structure of nematode

communities reflects the level of ecological maturity of the soil system. The author emphasised that the ratio of trophic groups allows assessment of the degree of ecosystem disturbance and the intensity of anthropogenic pressure. In the present study, the dominance of plant-parasitic forms combined with a high proportion of decomposers indicates an intermediate and unstable state of the agroecosystem. The high pathogenicity of certain groups was confirmed by S.R. Koenning & J.A. Wrather (2010), who established significant soybean yield losses caused by nematode invasions. Similar findings were reported by T.W. Allen *et al.* (2017), who emphasised that nematodes are among the dominant negative factors affecting global soybean production. The significant influence of agrotechnical measures, particularly the optimal saturation of crop rotations with host plants as the main limiting factor preventing the mass reproduction of cyst-forming nematodes, was demonstrated by A. Babych *et al.* (2024). In contrast, disruption of scientifically based crop rotation structures leads to the accumulation of nematodes in the soil and the formation of long-term invasive pressure.

Additionally, G.L. Tylka & C.C. Marett (2014) demonstrated the spatial heterogeneity of cyst-forming nematode distribution in crop rotations, confirming the influence of local agroecological conditions on the formation of community structure. From the perspective of functional ecology, T. Bongers & H. Ferris (1999) demonstrated that nematodes are key regulators in nutrient cycling. They ensure the transformation of organic matter and the transfer of energy between specific trophic levels. In this analysis, the high proportion of Rhabditida indicates active mineralisation processes and an intensive detrital flow. H. Ferris (2010) further developed the concept of “metabolic footprints”, which allows assessment of the contribution of nematodes to ecosystem functioning. In the studied agroecosystem, the ratio of trophic groups indicates an intermediate level of ecological stability characteristic of systems subjected to regular anthropogenic disturbance. The structural organisation of nematode food chains was also described by G.W. Yeates *et al.* (1993), who proposed a trophic classification as the basis for ecological analysis of soil communities. The results obtained herein

confirm the mixed nature of the community, with dominance of plant-parasitic and bacteriotrophic forms. Modern studies on the ecological condition of soil ecosystems demonstrate the substantial role of anthropogenic factors in shaping the structure of soil biota. In particular, the study by N. Kosovska *et al.* (2022) showed that the application of nanopreparations and biologically active substances significantly affected the composition and functioning of the soil microbiome, leading to restructuring of microbial communities and changes in the intensity of biogeochemical processes in soil. The authors emphasised that even relatively moderate agrochemical pressure may cause shifts in the structure of soil biocenoses, which is reflected in the functional organisation of the ecosystem. In turn, contemporary studies on the phytosanitary pressure within agroecosystems indicate that chemical plant protection products may exert indirect effects on soil biota. In the work of T. Stefanovska *et al.* (2025), it was established that neonicotinoids and butenolides affect not only target phytophagous organisms but also associated components of soil mesofauna, including nematodes. The authors noted that even at recommended application rates, these compounds are capable of modifying the structure of soil communities, indicating their indirect influence on trophic interactions within agroecosystems. The present findings regarding the dominance of plant-parasitic nematodes (Tylenchida) and the significant proportion of saprobiontic forms (Rhabditida) are consistent with these observations, since changes in the soil microbiocenosis, the intensity of mineralisation processes, and agrochemical pressure may collectively influence the structure of nematode communities. Thus, anthropogenic impact, including the use of modern agrochemical and biotechnological plant protection products, acts as an important factor shaping the functional organisation of soil biocenoses. Therefore, the results of the study confirm that the structure of the soybean nematode complex is the result of complex interactions among agrotechnical factors, edaphic conditions, and the biological characteristics of individual taxa. It simultaneously reflects processes of ecological transformation and partial compensation of the functional stability of the soil system.

CONCLUSIONS

The conducted research made it possible to systematically characterise the species composition, taxonomic structure, and ecological organisation of the phytoneamatode complex in soybean agroecosystems under conditions of the Right-Bank Forest-Steppe of Ukraine. It was established that the nematode community is characterised by a high level of taxonomic diversity and comprises 26 species belonging to 17 genera, 10 families, 5 orders, and 2 classes (Enoplea and Chromadorea), indicating a complex multilevel organisation of soil biota in soybean agroecosystems. The dominant taxonomic group is the class Chromadorea, accounting for more than 80% of the total community structure. The predominance of this class is determined by the high representation of the order Tylenchida, which forms the main phytoparasitic component. The most ecologically and agronomically significant species are *Pratylenchus penetrans* and *Tylenchorhynchus dubius*, which act as dominants and form a stable invasion background in the soybean rhizosphere. Their presence confirms a high phytopathogenic potential of the agroecosystem and an increased risk of reduced crop productivity. The subdominant level of the structure is represented by *Pratylenchus pratensis*, *Helicotylenchus dihystra*, *Paratylenchus nanus*, as well as certain aphelenchoid forms, which further complicate the trophic structure of the community and contribute to a multi-vector parasitic load on plant root systems. A significant proportion of saprobiontic and bacterivorous nematodes (Rhabditida) was recorded, indicating intensive organic matter decomposition processes and active functioning of the soil microbial component. This combination

of phytoparasitic and decomposer elements reflects the simultaneous action of two contrasting processes: phytosanitary stress and biological compensation within the soil system. Ecological analysis revealed that the nematode community is polydominant with a clearly expressed balance between dominant, subdominant, and rare species. This indicates an intermediate level of ecological stability of the agroecosystem, typical of intensively used agricultural lands. Thus, the phytoneamatode complex of soybean in the Right-Bank Forest-Steppe of Ukraine is a sensitive indicator of agroecological soil conditions, reflecting both the level of anthropogenic pressure and the functional activity of soil biota. The obtained results confirm the feasibility of using nematodes as bioindicators of agroecosystem health and may be applied in the development of environmentally oriented monitoring systems and protection strategies for soybean crops against soil-borne phytopathogens. Future research perspectives include a more detailed analysis of the spatiotemporal dynamics of dominant phytoneamatodes, assessment of their interactions with rhizosphere microbial communities, and development of integrated pest management strategies aimed at regulating their populations in soybean agroecosystems.

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Видовий склад та структура комплексу фітонематод сої в умовах Правобережного Лісостепу України

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Анотація. Метою дослідження було встановлення видового складу, таксономічної та екологічної структури комплексу фітонематод сої в умовах Правобережного Лісостепу України. У роботі застосовано польові маршрутні обстеження, лабораторні методи екстракції нематод із ґрунту та кореневої системи (лійковий метод Берманна та ситової сепарації), морфологічну і морфометричну ідентифікацію з використанням світлової мікроскопії, а також методи структурно-екологічного аналізу угруповань і варіаційної статистики. Встановлено, що комплекс нематод ризосфери сої включає 26 видів, які належать до 17 родів, 10 родин, п'яти рядів та двох класів, що засвідчило про високу таксономічну різноманітність ґрунтової біоти в агроценозі. Домінуючим був клас Chromadorea (понад 80 % від загальної структури), що вказує на функціональну спрямованість угруповання в умовах інтенсивного агровикористання. Найбільш чисельним був ряд Tylenchida, який визначає основну частку фітопаразитичного блоку та включає економічно значущі види *Pratylenchus penetrans*, *Tylenchorhynchus dubius*, *Helicotylenchus dihystra* та *Paratylenchus nanus*. Їх домінування засвідчило формування стабільного інвазійного потенціалу у ризосфері сої та наявність критичного фітосанітарного навантаження. Водночас суттєва частка сапробіонтних і бактеріотрофних нематод (Rhabditida та Serphalobidae) вказала на інтенсивні процеси мінералізації органічної речовини та активне функціонування мікробного блоку ґрунту. Поєднання високої частки фітопаразитичних і редуцентних форм формує функціонально неоднорідну структуру угруповання, що відображає одночасні процеси екологічного напруження та біологічної компенсації в агроєкосистемі. Структурний аналіз показав проміжний рівень екологічної стабільності системи, характерний для інтенсивно використовуваних сільськогосподарських угідь із періодичним порушенням ґрунтової структури та звуженням трофічних зв'язків. Отримані результати можуть бути використані для біоіндикаційної оцінки стану ґрунтів та розробки екологічно орієнтованих систем моніторингу і захисту посівів сої від фітонематод

Ключові слова: видовий склад; таксономічна структура; агроценози; *Pratylenchus penetrans*; *Tylenchorhynchus dubius*; біоіндикація ґрунтів

