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Soil Nematode Community Analysis of Four Chickpea Cultivated Areas in Aksaray, Türkiye

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ABSTRACT
This study investigates soil nematode communities in four distinct chickpea cultivation areas in Aksaray, Türkiye, to understand their composition, ecological functions, and impact on soil health. Chickpeas, as the nitrogen-fixing crop, play a vital role in sustainable agriculture, supporting soil health and providing economic benefits in rural areas. Soil nematodes, however, including plant-parasitic types like root-knot and lesion nematodes, pose risks to chickpea yield by damaging root systems, thus necessitating effective management strategies. The research took place from May to December 2023 at Düzce University's Nematology Laboratory. Soil samples from four locations (Akgülü, Bağınbaşı, Camili and Göllü) in Aksaray were collected and using the Baermann funnel technique nematodes were exracted. Nematode identification and ecological parameter analyses used for nematode-based biological monitoring were conducted with light microscopy and structured taxonomic keys. The study grouped the nematodes based on feeding behaviors, showing distinct profiles across locations: bacterivores dominated in Akgülü, while Bağınbaşı had a higher prevalence of plant-parasitic nematodes, suggesting soil biodiversity challenges. Analysis of soil food webs indicated a stressed ecosystem in Akgülü and enriched, structured soil in Bağınbaşı, as shown by higher enrichment and structure index values. These patterns highlight the effects of soil management on nematode communities, with biodiversity directly linked to soil health and chickpea productivity. Findings emphasize that integrated pest management, including crop rotation and resistant chickpea varieties, is essential to mitigate the effects of nematodes. The study provides insights into nematode-driven soil dynamics and underscores the need for further research on nematode impacts in various agroecosystems, particularly for sustainable chickpea cultivation.

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Türkiye Aksaray'da Nohut Yetiştirilen Dört Alanda Toprak Nematod Topluluklarının Analizi

ÖZET
Toprak nematod topluluklarının, kompozisyonları, ekolojik işlevleri ve toprak sağlığı üzerindeki etkileri araştırılmıştır. Nohut, azot bağlayıcı bir ürün olarak sürdürülebilir tarımda hayati rol oynamakta, toprak sağlığını desteklemekte ve kırsal alanlarda ekonomik faydalar sağlamaktadır. Ancak kök-ur ve lezyon nematodları gibi bitki paraziti türleri içeren toprak nematodları, kök sistemine zarar vererek nohut verimi için risk oluşturmakta ve bu nedenle etkili yönetim stratejilerini zorunlu kılmaktadır. Bu araştırmanın analizleri Mayıs-Aralık 2023 tarihlerinde Düzce Üniversitesi Nematoloji Laboratuvarında yürütülmüştür. Aksaray iline ait dört lokasyondan (Akgüüu, Bağınbaşı, Camili ve Göllü) toprak örnekleri toplanmış ve nematodları topraktan elde etmek için Baermann huni tekniği kullanılmıştır. Nematodların tanılanması ve ekolojik parametre analizleri, ışık mikroskobu ve yapılandırılmış bir taksonomik teşhis anahtarı kullanılarak gerçekleştirilmiştir. Çalışma, nematodları beslenme davranışlarına göre kategorize etmiş ve lokasyonlar arasında farklı profiller göstermiştir:

Entomoloji

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Akgülü'de bakteriovor nematodlar baskınken, Bağınbaşı'nda bitki-parazit nematodların daha yüksek oranda bulunduğu ve bu durumun toprak biyoçeşitliliği açısından zorluklar oluşturabileceği görülmüştür. Toprak besin ağlarının analizi, Akgülü'de stres altında bir ekosistemi, Bağınbaşı'nda ise daha zengin ve yapısal olarak düzenlenmiş bir toprak yapısını göstermiştir; bu durum, daha yüksek zenginleşme ve yapı indeks değerleri ile ortaya konmuştur. Bu modeller, toprak yönetiminin nematod toplulukları üzerindeki etkilerini vurgulamakta ve biyoçeşitliliğin toprak sağlığı ve nohut verimliliği ile doğrudan bağlantılı olduğunu göstermektedir. Bulgular, nematodların etkilerini azaltmak için ürün rotasyonu ve dayanıklı nohut çeşitleri de dahil olmak üzere entegre zararlı yönetiminin gerekli olduğunu vurgulamaktadır. Çalışma, Aksaray ilindeki bazı nohut ekilmiş alanlardaki nematod kaynaklı toprak dinamikleri hakkında fikir vermekte ve özellikle sürdürülebilir nohut yetiştiriciliği için farklı agroekosistemlerde nematod etkileri üzerine daha fazla araştırma yapılması gerekliliğini vurgulamaktadır.

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INTRODUCTION

Chickpea is a product that plays a crucial role in enhancing the global human food supply. Its nutritional profile has high benefits to for human health, providing a significant amount of protein, fiber, vitamins (such as B vitamins), and minerals (including iron, magnesium, and zinc). Its production can boost local economies, particularly in rural areas where smallholder farmers cultivate them. By serving as both a food source and a cash crop, chickpeas can improve livelihoods, reduce poverty, and foster community development (Merga and Haji, 2019). Moreover, chickpeas play a significant role in sustainable agriculture due to their nitrogen-fixing ability, which improves soil health and reduces the need for chemical fertilizers. This contributes to more sustainable farming practices that can support increased food supply without compromising environmental health. As climate change poses challenges to traditional food production, chickpeas offer a resilient solution due to their hardiness and adaptability to poorer soil conditions and drought. This makes them a strategic crop for ensuring long-term food supplies in changing environmental conditions (Devasirvatham and Tan, 2018).

Türkiye has consistently been one of the leading producers of chickpeas globally over the past decade. According to data from the Food and Agriculture Organization (FAO) and national agricultural statistics, Türkiye's chickpea production has seen fluctuations, with total annual output averaging around 500,000 to 800,000 tons (Muehlbauer and Sarker, 2017). The country benefited from favorable climate conditions and agricultural practices, leading to an increased yield per hectare. Notably, the production peaked in 2021, driven by both domestic demand and export opportunities, particularly to markets in the Middle East and Europe. Over the years, Turkish farmers have also focused on improving crop varieties and cultivation techniques to enhance productivity and sustainability, ensuring that chickpeas remain a crucial component of Türkiye's agricultural sector. However, challenges such as climate change and water scarcity could impact future production levels, necessitating ongoing adaptation and innovation in farming practices (Dellal & Unuvar, 2019).

Plant-parasitic nematodes play a significant role in agriculture and ecosystem dynamics, despite often being viewed as detrimental pests. Plant-parasitic nematodes attack the roots of plants, leading to reduced crop yields and compromised plant health. Their importance lies in their impact on soil microbiomes and nutrient cycling; when they infect plants, they can alter root development and induce stress responses that affect surrounding plant communities (Hugot et al., 2001). Additionally, they serve as indicators of soil health, with their presence reflecting the ecological balance within soil ecosystems. Understanding nematode populations and their interactions can help in developing integrated pest management strategies, promoting sustainable agricultural practices while minimizing crop losses. Consequently, while they are often pests, plant-parasitic nematodes also offer insights into soil ecology and agricultural resilience (Yeates, 2007).

Plant-parasitic nematodes also pose a significant threat to chickpea plants, affecting their growth and yield. The most common nematodes affecting chickpeas include root-knot nematodes and cyst nematodes. In addition to root-knot nematodes and cyst nematodes, chickpea plants can also be affected by other plant-parasitic nematodes such as lesion nematodes (Pratylenchus spp.) (Behmand et al., 2022; Behmand & Elekcioğlu, 2022). Lesion nematodes feed on plant roots, causing lesions that can lead to reduced water and nutrient uptake, impacting the overall plant health and yield of chickpeas. Dagger nematodes (Xiphinema spp.) are another type of plant-parasitic nematode that can infest chickpeas, transmitting viruses and causing damage to the root system. Infestations can vary in severity depending on nematode species, soil conditions, and plant health, making nematode management crucial for maintaining chickpea crop productivity. Strategies such as crop rotation, resistant varieties, and soil amendments can help mitigate nematode damage in chickpea cultivated fields. These nematodes can weaken the chickpea plants, making them more susceptible to other diseases and environmental stresses. Implementing integrated pest management strategies and maintaining good agricultural practices are essential for minimizing the impact of various plant-parasitic nematodes on chickpea crops (Perry et al., 2024).

A soil food web refers to the complex network of interactions between different organisms in the soil, including plants, fungi, bacteria, and various soil-dwelling animals like nematodes. It represents the flow of energy and nutrients through the soil ecosystem. The enrichment index (EI) is a calculation that provides the location of the food web along the enrichment trajectory (Powell, 2007). It is calculated as $100 \times (e/(e + b))$, where e represents the guilds indicating enrichment (such as Ba1 and Fu2) and b represents the basal conditions guilds. The EI assesses the food web response to available resources and is based on the expected responsiveness of opportunistic non-herbivorous guilds to food resource enrichment. In the context of nematodes, the terms "colonizer" and "persister" are used to describe two different strategies employed by nematodes to survive and reproduce in a given environment: Colonizer nematodes are characterized by their ability to quickly colonize and exploit new environments. They have a high reproductive capacity and can rapidly increase their population size in favorable conditions. These nematodes are often referred to as "r-strategists," emphasizing their focus on rapid reproduction to take advantage of abundant resources. Persister nematodes, on the other hand, exhibit a different strategy where they focus on survival under adverse conditions rather than rapid reproduction (Ferris et al., 2001). These nematodes may have mechanisms that allow them to endure stressful environments, such as drought or extreme temperatures, by entering a dormant or resistant state. They are more resilient to fluctuations in environmental conditions but may have slower reproductive rates compared to colonizer nematodes. Persister nematodes are often associated with a "K-strategist" strategy, emphasizing their ability to persist over time in stable but challenging environments. Understanding these different nematode strategies is important in managing agricultural systems and ecosystems, as it can affect their population dynamics, interactions with other organisms, and responses to environmental changes (Ferris & Bongers, 2009).

This study aims to understand the association between the soil nematode community and chickpea plantations and reveals the comprehensive analysis of soil nematodes from four different chickpea plantations in Aksaray, Türkiye.

MATERIAL and METHOD

This study was conducted at the Nematology Laboratory of the Agricultural Biotechnology Department of Düzce University Faculty of Agriculture between May 2023 and December 2023.

Sampling

Soil samples were collected during a field study in Aksaray province, Türkiye in April 2023. The sampling was conducted in chickpea growing areas of four different points in Aksaray province (Table 1).

Table 1. GPS coordinates of the sampling sites; the location and host plant association.
Çizelge 1. Örnekleme alanlarının GPS koordinatları; konum ve konukçu bitki ilişkisi

Village	Latitude	Longitude	Plant Association	Location
Akgülü	33, 836 55 79	38, 847 31 73	Chickpea	Aksaray
Bağınbaşı	33, 830 712 85	38, 796 159 71	Chickpea	Aksaray
Camili	33,964 640 46	38, 890 602 90	Chickpea	Aksaray
Göllü	33, 826 632 23	38, 847 96 43	Chickpea	Aksaray

A total of 100 samples of the arrangement layout were taken. For each of the four location, 25 soil samples were taken from an area of 15 x 15 cm and from 30 cm of soil depth. All samples were placed in zip-lock bags, stored in portable temperature containers during transportation, and stored in the Düzce University Nematology Laboratory.

Extraction of Nematodes

12 cm diameter petri dishes were prepared using the modified Baermann (1917) funnel technique. After separating the stones, 100 g of fresh soil was analyzed from each sample. Plastic trays were covered with filter paper and incubated for 48 hours to extract nematodes. At the end of 48 hours, alive nematodes were collected. Nematode solutions were heated to 60 °C before expiration and were operated. 4% formalin solution was used for fixation and preservation, and samples were preserved for continuous glass slide preparations. Extractions were labeled with the relevant number, transferred to plastic tubes and stored in the Duzce University Nematology Laboratory. The remaining soil samples are kept in the soil laboratory as a reserve for changes.

Preparation of Nematodes for Light Microscopy

Collected nematodes were rinsed with distilled water to remove any remaining residue. Extracted nematodes were placed in a 1.25 cm deep block containing 96% ethanol in an incubator at 40 °C. A few drops of a glycerol-formalin mixture containing 4% formalin were added and left in the room overnight. The next morning, a few drops of a solution consisting of five parts glycerol and 96% ethanol were added, then the two-thirds of the block were covered with a glass square. At the end of the day, a few drops of a glycerol:ethanol (5:95%) solution were added every other place to ensure the permeation of glycerol. The next day, each nematode was covered with glycerol and continuous glass slide preparations were made (Yoder et al., 2006).

Identification of Nematodes and Analysis of Ecological Parameters

Nematodes were handled manually using an Olympus CH microscope (Olympus Optical, Tokyo, Japan). Classification of nematodes was based on the taxonomic key of De Ley & Blaxter (2004) and additional taxonomic information by Hodda et al. (2006) and Andrássy (2002; 2005). Colonizer-persister soil maturity values were obtained according to the characteristics of nematode life cycle details in accordance with Bongers (1990; 1999). The classification of the reported types of nematodes was determined by Yeates et al. (1993) and Du Preez et al. (2022). To obtain the maturity degree of nematodes in the ecosystem, the structure index and richness index were calculated by Ferris et al. (2001) and Ferris & Bongers (2009). The Nematode Indicator Joint Analysis (Sieriebriennikov et al., 2014) programming system was used to analyze the strength of the food web, feeding type recognition and MI family indices.

RESULTS and DISCUSSION

The results based on the feeding types of nematode assemblage suggested that in chickpea cultivation region in Akgülü, bacterivores were found to be 66.6 % followed by plant parasitic nematodes (14.1%), fungivores (8.9%), omnivores (8.3%), predators (2.2%) and unicellular eucaryote feeders (0.0%); Bağınbaşı region: plant parasitic nematodes (58.2%), fungivores (19.4%), predators (9.2%), bacterivores (9.0%), omnivores (4.1%) and unicellular eucaryote feeders (0.0%); Camili region: plant parasitic nematodes (49.6%), bacterivores (23.7%), omnivores (20.4%), fungivores (6.3%), predators (0.0%) and unicellular eucaryote feeders (0.0%); Göllü region: bacterivores (38.0%), plant parasitic nematodes (37.4%), omnivores (20.4%), predators (2.2%), fungivores (2.0%) and unicellular eucaryote feeders (0.0%) (Fig. 1).

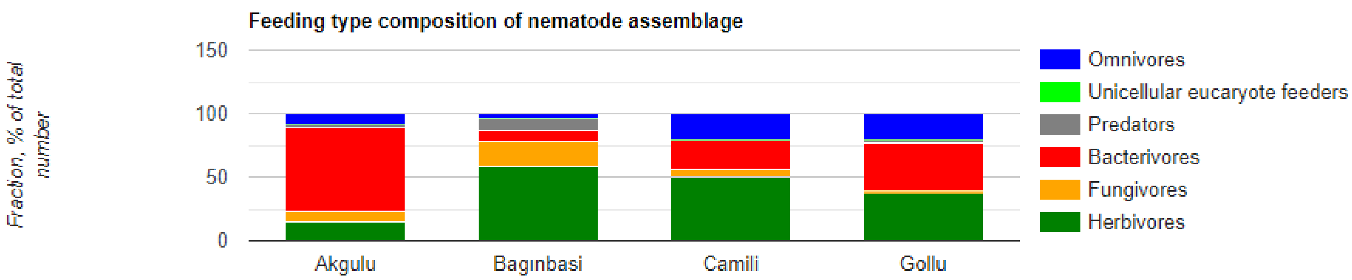

Figure 1. Feeding types of nematodes at different four region in Aksaray, Türkiye.
Şekil 1. Türkiye, Aksaray'daki farklı dört bölgede nematodların beslenme tipleri.

The results based on the classification of plant parasitic nematode feeding type differences, nematode assemblage in Akgülü region were found to be migratory endoparasites 43.9 % followed by epidermal/root hair feeders (33.7%), ectoparasites (22.5%) and sedentary parasites, semi-endoparasites and algal/lichen/moss feeders (0.0%); Bağınbaşı region: migratory endoparasites (29.7%), semi-endoparasites (28.9%), sedentary parasites (23.7%), ectoparasites (15.2%), epidermal/root hair feeders (2.5%) and algal/lichen/moss feeders (0.0%); Camili region: ectoparasites

(46.7%), epidermal/root hair feeders (28.9%), migratory endoparasites (24.4%) and sedentary parasites, semi-endoparasites and algal/lichen/moss feeders (0.0%); Göllü region: semi-endoparasites (35.8%), ectoparasites (29.6%), sedentary parasites (24.4%), migratory endoparasites (10.2%) and epidermal/root hair feeders and algal/lichen/moss feeders (0.0%) (Fig. 2).

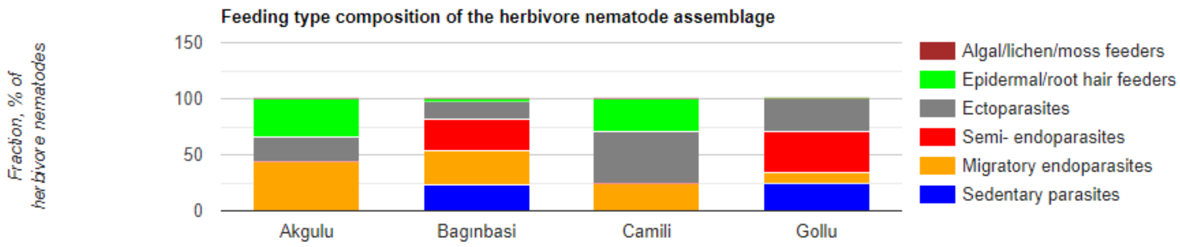

Figure 2. Distribution (%) of feeding types within the plant-parasitic nematodes from Aksaray, Türkiye.
Şekil 2. Türkiye, Aksaray'daki bitki paraziti nematodlar içinde beslenme tiplerinin dağılımı (%).

The results based on the classification of free-living nematode feeding type differences, nematode assemblages in Akgülü region were found to be bacterivores 77.5 % followed by fungivores (10.3%), omnivores (9.6%), predators (2.6%) and unicellular eucaryote feeders (0.0%); Bağınbaşı region: fungivores (46.6%), predators (22.0%), bacterivores (21.7%), omnivores (9.7%) and unicellular eucaryote feeders (0.0%); Camili region: bacterivores (47.1%), omnivores (40.4%), fungivores (12.5%) and predators and unicellular eucaryote feeders (0.0%); Göllü region: bacterivores (60.7%), omnivores (32.5%), predators (3.6%), fungivores (3.2%) and unicellular eucaryote feeders (0.0%) (Fig. 3).

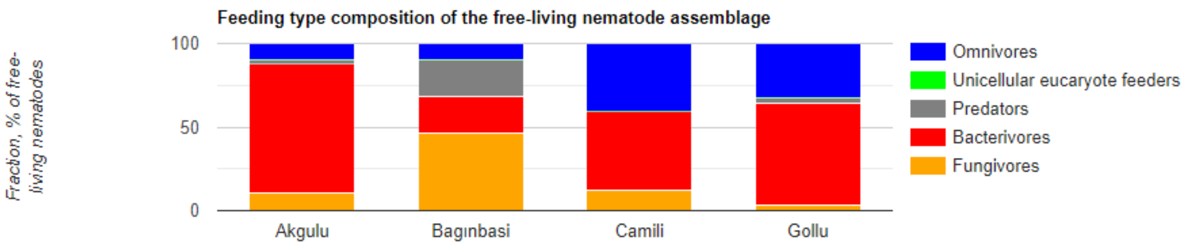

Figure 3. Distribution (%) of feeding types within the free-living nematodes from Aksaray, Türkiye.
Şekil 3. Türkiye, Aksaray'daki serbest yaşayan nematodlar içinde beslenme tiplerinin dağılımı (%).

The results based on the classification of free-living nematode c-p classification differences in Akgülü region were CP2 (87.7%), CP5 (8.8%), CP4 (3.4%), CP1 (0.1%), and CP3 (0.0%); Bağınbaşı region: CP2 (53.6%), CP5 (31.8%), CP4 (14.6%) and CP1 and CP3 (0.0%); Camili region: CP2 (47.1%), CP5 (29.3%), CP4 (23.6%), CP1 and CP3 (0.0%); Göllü region: CP2 (56.1%), CP5 (30.8%), CP4 (13.1%), CP1 and CP3 (0.0%) (Fig. 4).

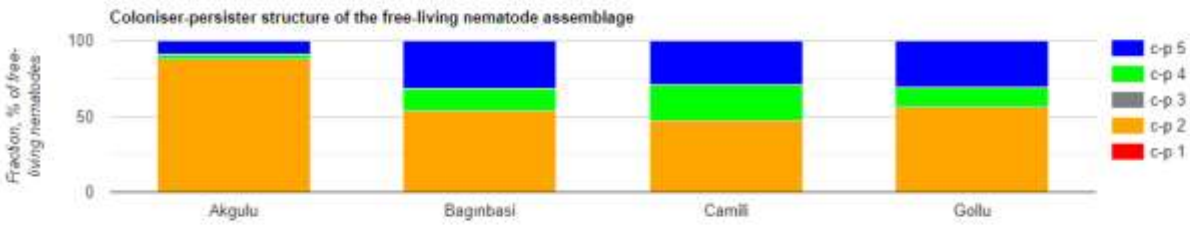

Figure 4. Free-living nematode c-p classification from four region in Aksaray, Türkiye.
Şekil 4. Türkiye, Aksaray'daki dört bölgeden serbest yaşayan nematode c-p sınıflandırması.

The results based on the classification of plant parasitic nematode cp class differences, nematode assemblages in Akgülü region were PP3 (66.3%), PP2 (33.7%) and PP4, PP5 (0.0%); Bağınbaşı region: PP3 (95.5%), PP2 (2.5%), PP5 (2.0%) and PP4 (0.0%); Camili region: PP3 (52.3%), PP2 (46.5%), PP5 (1.3%) and PP4 (0.0%); Göllü region: PP3 (86.6%), PP2 (13.4%) and PP4, PP5 (0.0%) (Fig. 5).

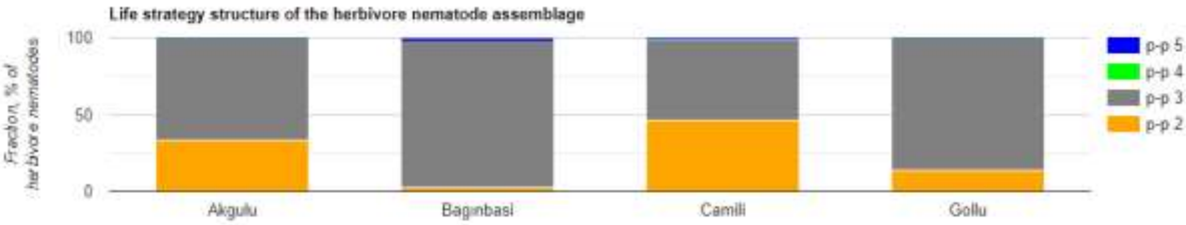

Figure 5. Plant parasitic nematode c-p classification from four region in Aksaray, Türkiye.
Şekil 5. Türkiye, Aksaray'daki dört bölgeden bitki paraziti nematod c-p sınıflandırması.

The enrichment index analysis (EI), results showed the highest enrichment level in the Bağınbaşı region (EI value: 28.15) followed by; the Akgülü region (EI value: 10.25), Göllü region (EI value: 5.13) and Camili region (EI value: 0.0). According to the structure index analysis (SI), results showed the highest structure level in Camili region (SI value: 80.65) followed by; Bağınbaşı region (SI value: 80.30), Göllü region (SI value: 62.71) and Akgülü region (SI value: 39.84).

Food web analysis is constructed to indicate whether the soil community is basal (and inferred stressed), enriched, or structured and stable. As a dynamic and evolving framework, we assess soil food web conditions by analyzing the position of nematode faunal composition within the faunal profile. Results showed that the Bağınbaşı region's nematode assemblage was mature, fertile with a modarete C:N value, high bacterial and fungal activity and suppressive soil. Nematode assemblage of the Akgülü region occurred at degraded, depleted, with high C:N value, more fungal and bacterial activity and some conductive, some suppressive soil types.

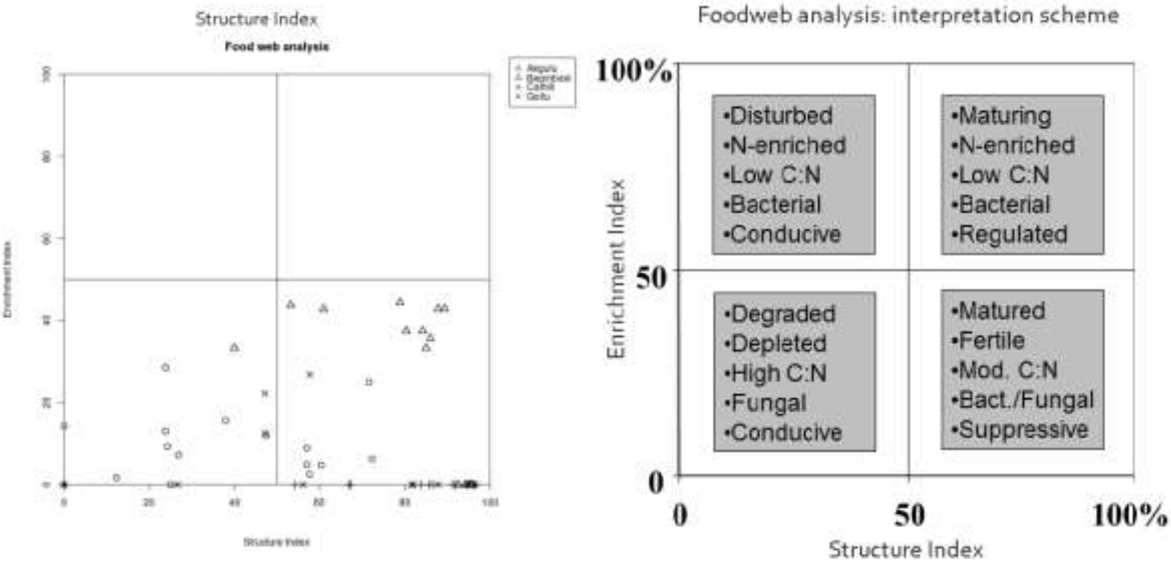

Figure 6. Food web analysis (Enrichment/Structure indices) from four region in Aksaray, Türkiye.
Şekil 6. Türkiye, Aksaray'daki dört bölgeden besin ağı analizi (Zenginleşme/Yapı indeksleri).

The findings of this study provided valuable data to understand the structure and diversity of soil nematode communities in four different chickpea growing areas in Aksaray. The distribution of soil nematodes is shaped by the effects of agricultural practices, environmental conditions and soil properties in these regions. The distribution of nematodes according to different feeding types can be interpreted as an indicator of ecosystem health and can help determine strategies to increase sustainability in agricultural production.

Bacterivorous and Fungivorous Nematodes

The dominance of bacterivorous nematodes (66.6%) in the Akgülü region indicates that the microbial activity of this area is high and the organic matter decomposition process is accelerated. Bacterivorous nematodes play important roles in the soil ecosystem, decompose organic matter through microorganisms and contribute to the availability of nutrients to plants. This can increase soil fertility and facilitate plant nutrient uptake. At the same time, the low rates of fungivorous nematodes (8.9%) indicate an ecosystem where the fungal population is not dominant. Fungivores can contribute to the control of pathogenic fungi by consuming fungi, so the lower rates of these nematodes may indicate that the risk of pathogenic fungi in the ecosystem is low.

In the Bağınbaşı region, the high rate of plant parasitic nematodes (58.2%) indicates that this area is heavily infested with harmful species. The low levels of bacterivores and omnivores (9.0% and 4.1%) may suggest that the ecosystem is under pressure and biodiversity is low. This situation points to the need to increase biodiversity for sustainable agriculture. Biodiversity naturally keeps harmful nematodes under control, so low rates of bacterivores and omnivores may indicate the lack of such balancing mechanisms.

Omnivorous and Predatory Nematodes

The high rate of omnivorous nematodes (20.4%) in the Camili region suggests that this ecosystem has a more balanced structure. Omnivorous nematodes are generally found in more mature and stable soil ecosystems and are therefore considered an indicator of soil health. The complete absence of predatory nematodes (0.0%) may indicate that another important element of biodiversity is missing in this ecosystem. Predatory nematodes are natural predators that control populations of harmful nematodes, and the absence of these species may lead to uncontrolled proliferation of plant parasitic nematodes.

The balanced distribution of bacterivorous and omnivorous nematodes in the Göllü region (38.0% and 20.4%) indicates that this region is more ecologically stable and biodiversity is better preserved. However, the high rate of plant parasitic nematodes (37.4%) reveals that there is a significant risk threatening plant health in this area. This situation emphasizes the need to develop pest management strategies.

Plant Parasitic Nematodes and Integrated Pest Management

One of the most important findings of the study is that plant parasitic nematodes are dominant in varying proportions among regions. Plant parasitic nematodes can cause significant yield losses, especially in plants that attack the root system, such as chickpeas. It was determined that migratory endoparasites (43.9%) were dominant in the Akgülü region, indicating that the root system was seriously damaged. Similarly, the co-existence of migratory endoparasites and sedentary parasites in the Bağınbaşı region indicates that harmful nematode management should be more comprehensive. These situations necessitate more effective implementation of integrated pest management strategies in chickpea fields; crop rotation, the use of resistant varieties and the application of biological control methods can reduce the effects of these pests.

Soil Food Web Analysis and Soil Health

The fact that the nematode communities in the Akgülü region are largely composed of bacterivorous nematodes (66.6%) indicates that this area has high organic matter transformation and microorganism activity. This finding is consistent with studies indicating that bacterivorous nematodes are dominant in areas with high organic matter content (Ferris et al., 2001). However, the high C: N values in Akgülü indicate that the soil is stressed with some high fungal activities.

In the Bağınbaşı region, it was determined that plant parasitic nematodes were dominant at a rate of 58.2%. This supports studies such as Perry et al. (2024) and Bongers (1990), which emphasize plant health risks in areas where damaging nematode populations are dominant and biodiversity is low. The relatively high rate of omnivorous nematodes (20.4%) in the Camili region indicates that the ecosystem in this region has a more mature and balanced structure.

Ecological and Agricultural Implications of the Results

The high nematode activities determined in the Akgülü and Bağınbaşı regions indicate that integrated pest management strategies should be implemented. Nematode biological indicator models developed by Ferris and Bongers (2009) suggest solutions such as crop rotation and the use of resistant varieties to improve such stressed and unenriched ecosystems.

The 37.4% plant parasitic nematode population detected in the Göllü region represents an important threat that can damage the chickpea root system and lead to yield losses. This finding supports the studies by Perry et al. (2024) that draw attention to the economic effects of plant-parasitic nematodes.

Previous studies showed that nematode research in the Aksaray region of Türkiye focuses on root-knot nematodes that threaten potato and wheat production, particularly the distribution and effects of quarantine species such as Meloidogyne chitwoodi throughout the country (Evlice & Bayram, 2016). Similarly, the wheat gall nematode

Anguina tritici is observed with high infection rates in some provinces of Central Anatolia, especially in provinces such as Aksaray (Elmalı, 2002). Ditylenchus dipsaci was observed in garlic production in Aksaray province (Ateş Sönmezoglu et al., 2019). Unfortunately, there are not many studies on the nematode fauna of the region other than these 3 plant parasitic nematode species.

Protection of Biodiversity and Soil Health

The high enrichment index value (EI: 28.15) in the Bağınbaşı region showed that this area is biologically richer and microorganism activities are more intense. This situation is closely related to diversity indices and soil structure and represents a balanced ecosystem as defined by Ferris et al. (2001).

The low structure index value in the Akgülü region (SI: 39.84) indicates the insufficient biodiversity and low soil health of this area. This finding is consistent with the studies on weak soil systems defined by Yeates (2007). In such areas, it is recommended to implement solutions such as organic matter supplementation, farm gûre use, and biological control measures.

In this study, soil food web analyses were also conducted and these analyses revealed the effects of nematode communities in the field on soil health. The highest enrichment index value (EI: 28.15) was found in the Bağınbaşı region and it was determined that this region has a richer soil food web. Rich soil food webs indicate healthy soils with high biodiversity and microorganism activities. In contrast, lower enrichment and structure index values in the Akgülü and Göllü regions suggest that these regions have more stressed and degraded ecosystems. Especially the low structure index in the Akgulu region (SI: 39.84) indicates that soil health in this area is poor and that remedial agricultural practices are needed.

In conclusion, the data obtained in the study highlight the diversity of nematode communities in different agricultural areas and the effects of these communities on soil health. These findings may guide the development of pest management strategies in chickpea farming. In particular, the use of nonhost crop rotations, resistant varieties against plant parasitic nematodes, and the application of biological control methods may increase sustainability in agricultural production. In addition, this study reveals that further research is needed to better understand the role of soil nematodes in agroecosystems.

Researchers' Contribution Rate Declaration Summary

The authors declare that they have contributed equally to the article.

Statement of Conflict of Interest

The authors declare no conflict of interest.

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