Soil Nematode Diversity in Kishtwar High Altitude National Park, (Jammu and Kashmir) India

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***Abstract*—Soil nematodes are key components of soil ecosystems and serve as sensitive bioindicators of soil health and ecological functioning. The present study was conducted to assess soil nematode diversity in Kishtwar High Altitude National Park, Jammu & Kashmir, India, an ecologically fragile and understudied alpine protected area of the Western Himalaya**

A total of diverse nematode genera representing different trophic groups were recorded, including bacterivores (Rhabditis, Cephalobus, Acrobeloides), fungivores (Aphelenchus, Aphelenchoides), plant-parasites (Tylenchus, Ditylenchus, Pratylenchus), omnivores (Aporcelaimellus, Eudorylaimus), and predators (Mononchus, Clarkus). Bacterivorous nematodes were the most dominant group, indicating active microbial decomposition pathways in alpine soils, while plant-parasitic nematodes showed relatively low abundance, reflecting minimal anthropogenic disturbance.

***Index Terms*—Soil nematodes, biodiversity, alpine ecosystem, Himalays, soil health, Kishtwar High Altitude National Park.**

I. INTRODUCTION

Soil is a complex and dynamic ecosystem that supports a wide range of organisms which play crucial roles in nutrient cycling, organic matter decomposition, and overall ecosystem functioning. Among soil biota, nematodes are one of the most abundant and ecologically significant groups. Due to their diversity in feeding habits and rapid response to environmental changes, soil nematodes are widely recognized as effective bioindicators of soil health and ecosystem stability.

Nematodes occupy multiple trophic levels in the soil food web, including bacterivores, fungivores, plant parasites, omnivores, and predators. This functional diversity allows them to regulate microbial populations, influence nutrient mineralization, and interact with plant roots, thereby affecting both soil fertility and plant productivity. Changes in nematode community structure often reflect alterations in soil conditions caused by natural factors such as climate and vegetation, as well as anthropogenic disturbances.

High-altitude ecosystems, particularly those in the Himalayan region, are highly sensitive and ecologically fragile due to extreme climatic conditions, low temperatures, and limited nutrient availability. The Western Himalaya, including the region of Kishtwar High Altitude National Park in Jammu & Kashmir, represents a unique biodiversity hotspot characterized by alpine meadows, subalpine forests, and diverse microhabitats. Despite their ecological importance, these regions remain relatively underexplored with respect to soil microfaunal diversity, especially soil nematodes.

Previous studies on nematode diversity in India have largely focused on agricultural and temperate systems, while alpine and protected ecosystems have received comparatively little attention. As a result, baseline information on nematode community structure, distribution patterns, and ecological roles in high-altitude Himalayan soils is limited. Understanding these communities is essential for assessing soil ecosystem functioning and detecting early signals of environmental change.

II. OBJECTIVE

The present study aims to investigate soil nematode diversity in different habitats of Kishtwar High Altitude National Park. The objectives include identifying the major nematode genera present, analyzing their trophic structure, and provide baseline data for future ecological monitoring and contribute to a better understanding of soil food web dynamics in high-altitude Himalayan ecosystems.

III. MATERIAL AND METHODS

3.1 Site description

Kishtwar High Altitude National Park (KHANP), is one of the most ecologically significant protected areas of the western Himalayas. Located between 33°20′–34°15′ N latitude and 75°25′–76°10′ E longitude, the park covers an area of approximately 2,190.50 km² and encompasses a remarkable altitudinal range extending from about 1,700 m to over 6,000 m above sea level (Wani et al., 2020). Established in 1981, KHANP forms an important component of the Greater Himalayan biodiversity corridor and supports a wide variety of habitats, including temperate coniferous forests, subalpine woodlands, alpine meadows, glaciated valleys, and permanently snow-covered peaks.

The diverse habitats and altitudinal heterogeneity of KHANP offer an excellent natural laboratory for investigating patterns of soil nematode diversity.

Table1: Characteristics of Kishtwar National High-Altitude Park.

Characteristics	
Total area	2,190.5 sq km
Average annual rainfall	700 to 1,500 mm plus heavy snowfall at higher elevations.
Climate	Temperate to alpine with cold winters and cool summers.
Temperature	Summer 0°C to 25°C Winter -25°C to 10°C
Soil type	Brown Forest soil, Mountain Meadow soil, Shallow, stony soil, Alluvial soil,
Soil pH	Ranges 4.8-7 (Slightly acidic to moderately acidic) depending on altitude and vegetation.
Vegetation	Temperate coniferous forests, sub-alpine birch–fir forests, alpine scrub, and alpine meadows.

3.2 Soil sampling and nematode extraction

Soil samples were collected from representative habitats across Kishtwar High Altitude National Park, Jammu and Kashmir, India, encompassing different vegetation types and altitudinal zones. Sampling was carried out across different seasons in order to capture temporal variation in the active soil nematode community. At each sampling site, soil cores were taken from the upper 10–15 cm layer after carefully removing surface litter and debris.

Collected soil samples were processed for nematode extraction using a combination of sieving, decantation, and the modified Baermann funnel technique, which is widely used for isolating active nematodes from soil. The soil suspension was first passed through a series of sieves to remove coarse particles and homogenize the sample. The resulting suspension was then placed on tissue-supported mesh in Baermann funnels filled with clean water and left undisturbed for 24–48 hours, allowing motile nematodes to migrate into the water phase.

After extraction, the nematode suspension was concentrated by sedimentation and observed under a stereomicroscope. Recovered nematodes were gently heat-killed and fixed in a formalin–glycerol solution, followed by processing to anhydrous glycerol for permanent slide mounting. Identification was carried out under a compound microscope using standard taxonomic keys based on morphological and morphometric characteristics. Nematodes were subsequently classified into trophic groups for ecological interpretation and diversity analysis.

3.3 Nematode identification

The extracted nematodes were tentatively identified to genus rank, were observed under Stereoscopic Microscope for generic identification.

IV. RESULT

A comprehensive survey of soil nematodes in Kishtwar High Altitude National Park (KHANP), Jammu and Kashmir, revealed a rich and diverse nematode fauna. A total of 91 genera belonging to multiple taxonomic groups were identified from soil samples collected across different habitats and altitudinal zones during the study period. The high generic diversity observed reflects the ecological complexity and relatively undisturbed nature of the alpine ecosystem.

4.1 Overall Soil Nematode Diversity

The survey of soil nematodes conducted in Kishtwar High Altitude National Park (KHANP), Jammu & Kashmir, revealed a rich and diverse nematode fauna.

A total of 91 genera belonging to different families of nematodes were recovered from soil samples collected from different habitats and altitudinal zones. The nematode community comprised both free-living and plant-parasitic forms, representing all major trophic guilds. The overall diversity reflected the heterogeneous nature of the park's ecosystems, which include alpine meadows, coniferous forests, mixed forests, shrublands, grasslands, and riparian habitats. The occurrence of numerous free-living nematodes, particularly bacterivorous and omnivorous forms, indicated a biologically active soil environment with well-developed microbial communities. Predatory nematodes were also consistently recorded, suggesting a stable and mature soil food web.

The recovery of a large number of genera demonstrates that the protected ecosystems of KHANP support a highly diverse nematode assemblage and provide suitable habitats for a broad spectrum of soil microfauna.

4.2 Taxonomic Composition of Soil Nematodes

The identified nematodes represented a broad range of taxonomic groups distributed among several orders and families. The majority of the recorded genera belonged to the orders Dorylaimida, Tylenchida, Rhabditida, Mononchida, Aphelenchida, Araeolaimida, and Plectida. The taxonomic composition indicated the presence of both colonizer (cp-1 and cp-2) and persister (cp-4 and cp-5) nematodes, suggesting relatively undisturbed soil conditions across much of the study area.

4.3 Trophic Group Composition

The soil nematode community consisted of all five principal trophic groups, namely bacterivores, fungivores, plant parasites, omnivores, and predators. Bacterivorous nematodes constituted the most abundant trophic group and were represented by genera such as Rhabditis, Acrobeloides, Cephalobus, and Panagrolaimus. Their dominance reflects active bacterial decomposition and nutrient mineralization within the soil ecosystem. Fungivorous nematodes, including Aphelenchus and Aphelenchoides, were common in soils rich in decomposing organic matter, indicating the importance of fungal-mediated decomposition pathways. Plant-parasitic nematodes comprised genera belonging mainly to Tylenchida and were generally less abundant than free-living nematodes. Their relatively low abundance is consistent with the natural vegetation and absence of intensive agricultural disturbance within the protected area. Omnivorous and predatory nematodes, represented by genera such as Aporcelaimellus, Eudorylaimus, Mononchus, and Clarkus, occurred in most habitats and contributed significantly to the complexity and stability of the soil food web.

4.4 Habitat-wise Diversity

Marked differences in nematode diversity were observed among the various habitat types sampled within KHANP. Forest ecosystems exhibited the highest generic richness owing to greater litter accumulation, higher soil organic matter, and favourable moisture conditions. Mixed forests supported a more heterogeneous nematode assemblage than pure conifer stands due to greater plant diversity. Alpine meadows contained abundant bacterivorous and fungivorous nematodes adapted to herbaceous vegetation and seasonal nutrient inputs. Grasslands supported a moderate diversity dominated by bacterial feeders, while shrublands showed relatively balanced trophic composition. Riparian habitats exhibited comparatively high abundance because of continuously moist soil conditions and elevated microbial activity. In contrast, exposed rocky and sparsely vegetated alpine sites generally supported fewer genera because of harsher environmental conditions. Overall, habitat heterogeneity was one of the major factors contributing to the high nematode diversity recorded from the park.

4.5 Altitudinal Variation in Nematode Communities

Nematode diversity and community composition varied considerably along the altitudinal gradient. Lower elevations supported the highest abundance and generic richness due to relatively favourable temperatures, deeper soils, and greater vegetation cover. Mid-altitude sites also maintained diverse communities but showed increased representation of omnivorous and predatory taxa. At higher elevations, total abundance and generic richness gradually declined, reflecting lower temperatures, shorter growing seasons, reduced organic matter decomposition, and limited vegetation. Nevertheless, several genera characteristic of alpine environments remained consistently present throughout the higher zones, indicating adaptation to extreme environmental conditions. Changes in trophic structure along the altitudinal gradient suggest that environmental factors such as soil moisture, temperature, pH, vegetation type, and organic carbon content strongly influence nematode community composition.

4.6 Seasonal Variation in Soil Nematode Diversity

Seasonal fluctuations were evident in both nematode abundance and community composition. The highest diversity and abundance were generally recorded during spring and summer when favourable soil temperature, adequate moisture, and increased microbial activity promoted nematode reproduction and growth. Autumn samples continued to exhibit relatively high diversity because of increased litter deposition and organic matter decomposition. Winter samples showed the lowest abundance and diversity owing to reduced biological activity, frozen or cold soils, and limited food availability. Despite seasonal declines, several cold-adapted genera remained active throughout the year, demonstrating their ability to survive under alpine climatic conditions. Overall, seasonal variation reflected changes in environmental conditions and resource availability within the soil ecosystem.

4.7 Dominant and Rare Genera

Among the 91 recorded genera, several occurred consistently across multiple habitats and seasons and were regarded as dominant members of the soil nematode community. Dominant genera were primarily bacterivorous and omnivorous taxa, reflecting the importance of microbial decomposition processes in the park's soils. Predatory genera were generally less abundant but were widely distributed, indicating the presence of a complex and balanced soil food web. Plant-parasitic genera were comparatively infrequent and usually confined to areas supporting dense herbaceous vegetation. Several genera were represented by only a few individuals and were recorded from a single habitat or sampling season. These rare taxa may represent habitat specialists with narrow ecological requirements or species naturally occurring at low population densities. The coexistence of abundant dominant genera together with numerous rare taxa contributes substantially to the overall biodiversity of KHANP and highlights the ecological significance of its protected alpine ecosystems.

TABLE II: List of Nematode genera with their corresponding trophic group found in Kishtwar National High-Altitude Park (KNHAP).

Trophic group	Nematode Genera
Herbivores (Phytophagous)	
	Basiria
	Cephalenchus
	Criconema
	Criconemoides
	Helicotylenchus
	Hoplolaimus
	Hirschmaniella
	Longidorous
	Malenchus
	Merlinius
	Oriverutus
	Paratylenchus
	Pratylenchus
	Tylenchus
	Tylenchorhynchus
	Trichodorous
	Xiphinema
Bacterivores (bacteriophagous)	Achromadora
	Acrobeles
	Acrobeloides
	Caenorhabditis
	Cephalobus,
	Cervidellus
	Chiloplacus
	Chronogaster
	Coarctadera
	Cruznema
	Curviditis
	Cuticularia
	Diplogasteritus
	Diploscapter
	Eucephalobus
	Eumonhystera
	Geomonhystera
	Halicephalobus
	Heterocephalobus
	Mesorhabditis
	Metadiplogaster
	Monhystera

	Monhystrella
	Neotylocephalus
	Panagrellus
	Panagrolaimus
	Plectus,
	Prismatolaimus
	Protorhabditis
	Rhabditis
	Rhabdolaimus
	Teratorhabditis,
	Udonchus
	Ypsilonellus
	Zeldia
Fungivores (mycophagous)	
	Adenolaimus,
	Aphlenchiodes
	Aphelenchus
	Belondira
	Ditylenchus
	Leptonchus
	Tylenchorhynchus
	Tyleptus
Algivores (Algal feeders)	
	Achromadora
	Punctodora
Omnivores	
	Belondira
	Dorylaimus
	Dorylaimellus
	Eudorylaimus
	Labronema
	Laimydorus
	Lordellonema
	Mesodorylaimus
	Prodorylaimus
	Thornenema
	Moshajia
Predators	
	Aporcelaimellus
	Aporcelaimus
	Aquatides
	Butlerius
	Clarkus
	Discolaimium
	Discolaimus
	Dicolaimoides
	Ironus
	Makatinus
	Mononchoides
	Mononchus
	Mylonchulus
	Neoactinolaimus
	Nyglaimus
	Seinura
	Tobrilus
	Tripyla

V. DISCUSSION

The present study recorded 91 soil nematode genera representing all major trophic groups, including bacterivores, fungivores, plant parasites, omnivores, and predators, indicating a highly diverse and well-structured soil nematode community in Kishtwar High Altitude National Park. Habitat characteristics such as vegetation type, soil moisture, organic matter, and soil physicochemical properties strongly influenced nematode diversity and distribution. Areas with higher vegetation cover and organic matter supported greater abundance and richness of nematodes by providing favorable conditions for microbial growth. Increasing altitude generally reduced diversity because of lower temperatures, shorter growing seasons, and limited nutrient availability, although several genera were well adapted to alpine environments. The documentation of 91 nematode genera representing all trophic groups underscores the ecological significance of Kishtwar High Altitude National Park as a reservoir of soil biodiversity. Conserving this below-ground diversity is essential for maintaining nutrient cycling, decomposition, soil fertility, and ecosystem resilience. Because nematode communities respond rapidly to environmental disturbances and climate change, they serve as effective bioindicators for monitoring ecosystem health and supporting long-term conservation and management of fragile Himalayan alpine ecosystems.

VI. CONCLUSION

The present study provides the first comprehensive assessment of soil nematode diversity in Kishtwar High Altitude National Park, Jammu & Kashmir, India. A total of 91 nematode genera belonging to all major trophic groups were recorded, demonstrating the rich below-ground biodiversity and functional complexity of this alpine ecosystem. The diversity and distribution of nematodes were strongly influenced by habitat characteristics, including vegetation type, soil moisture, organic matter, and altitude. The presence of all trophic groups indicates a well-balanced soil food web and a relatively undisturbed ecosystem. The findings highlight the important ecological role of soil nematodes in nutrient cycling, decomposition, microbial regulation, and maintaining soil health. As sensitive indicators of environmental change, nematode communities can serve as valuable tools for monitoring ecosystem condition and assessing the impacts of climate change and other disturbances in Himalayan landscapes. This study establishes essential baseline information on soil nematode diversity in Kishtwar High Altitude National Park and emphasizes the need for continued research and long-term monitoring to support biodiversity conservation and sustainable management of fragile alpine ecosystems.

VII. CONFLICT OF INTEREST

There is no conflict of interest regarding the publication of this paper. The research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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