DIVERSITY OF MILLIPEDES (ARTHROPODA: DIPLOPODA) FROM AGRICULTURAL LANDSCAPES OF BULDANA DISTRICT, MAHARASHTRA (INDIA)

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Abstract
Millipedes (Arthropoda: Diplopoda) are important soil macrofauna that contribute significantly to litter decomposition, nutrient cycling, and the maintenance of soil fertility. The present study, conducted from February 2022 to January 2025, systematically assessed the diversity of millipedes in agricultural landscapes of Buldana district, Maharashtra (India). Repeated and seasonally stratified surveys were carried out across croplands, orchards, fallow lands, and semi-natural field margins. A total of eight species belonging to three orders, five families, and seven genera were recorded, reflecting both cosmopolitan, disturbance-tolerant taxa (Anoplodesmus saussurii, Orthomorpha coarctata, Oxidus gracilis, Trigoniulus corallinus, Xenobolus carnifex) and habitat-sensitive species (Harpaphe haydeniana, Julus terrestris, Polydesmus sp.). Generalist species were widespread across all talukas, indicating ecological plasticity, whereas sensitive taxa were restricted to semi-natural habitats, highlighting their vulnerability to anthropogenic pressures. Seasonal abundance patterns revealed peaks during the monsoon and post-monsoon periods, driven by high soil moisture and organic matter availability, with sharp declines in summer. The findings demonstrate that agricultural landscapes, despite intensive cultivation, can sustain diverse millipede assemblages that play essential roles in ecosystem functioning. However, unsustainable farming practices including pesticide application, residue burning, and frequent tillage, pose significant threats to sensitive species and overall soil biodiversity. Conservation measures such as maintaining litter-rich field margins, reducing chemical inputs, and adopting organic amendments are crucial to preserve millipede diversity and ensure long-term soil health and agricultural sustainability in the region.

Keywords: *Millipedes, Diplopoda, agricultural landscapes, Buldana district, species diversity, ecological roles, conservation.*

Introduction

Millipedes (Arthropoda: Diplopoda) constitute one of the most diverse groups of terrestrial arthropods, with more than 12,000 species described worldwide. They are integral components of soil ecosystems, primarily functioning as detritivores that accelerate litter decomposition, enhance nutrient cycling, and contribute to the formation of humus and overall soil fertility. Through fragmentation of organic matter and stimulation of microbial activity, millipedes play a crucial role in maintaining soil health and ecological balance (Chakraborty, 2018; Patne, *et al.*, 2024b). Their ecological services extend beyond decomposition, as their burrowing behaviour improves soil aeration and water retention, thereby supporting sustainable agricultural productivity.

Studies conducted across different parts of India have demonstrated rich diversity and distinct distribution patterns of millipedes in varied habitats ranging from forests and hill ranges to croplands and peri-urban landscapes. Investigations in the Western Ghats, Rajgurunagar, and southern Tamil Nadu have highlighted species composition, abundance, and seasonal variations in millipede communities, emphasizing the influence of environmental gradients and microhabitat conditions (Patil, *et al.*, 2018; Usha, *et al.*, 2021; Ramanathan, Kumar, and Srinivasan, 2023). Similarly, research from Marathwada and western Maharashtra has provided insights into the diversity, seasonal dynamics, and ecological significance of Diplopoda, pointing to their resilience in some agroecosystems as well as their vulnerability to intensive agricultural practices (Deshmane, 2019, 2020; Patne *et al.*, 2024a).

At a broader scale, studies from Cameroon rainforests and other tropical regions reveal how altitudinal gradients, microclimatic conditions, and litter availability shape millipede distribution and diversity (Makon, *et al.*, 2025). In Indian agricultural landscapes, millipede assemblages are increasingly being recognized as sensitive indicators of habitat disturbance. Investigations from Achalpur, Amravati, and Mehkar in Buldana district have recorded distinct patterns of species richness and abundance, while highlighting the impacts of pesticides, tillage, and residue management on millipede populations (Ahsan, *et al.*, 2022; Rodge, *et al.*, 2022; Thakare and Kakde, 2022). These findings collectively underscore the importance of conserving millipede diversity in intensively cultivated regions.

Despite these contributions, systematic studies on millipede diversity from the agricultural landscapes of Buldana district remain limited. Most available

work has focused either on urban or semi-natural habitats, with less emphasis on the ecological implications of millipedes in agroecosystems. Given the central role of millipedes in soil processes and their sensitivity to anthropogenic pressures, there is a pressing need to assess their diversity, distribution, and ecological significance in this region.

The present study addresses this gap by documenting the diversity of millipedes from selected agricultural landscapes of Buldana district, Maharashtra, thereby contributing to a broader understanding of soil biodiversity and its conservation in human-modified ecosystems.

Materials And Methods

Systematic field surveys were conducted across selected agricultural landscapes of Buldana district using standard collection and preservation techniques. Specimens were identified through detailed morphological examination following established taxonomic keys.

Study Area: The study was conducted in agricultural landscapes across different talukas of Buldana district, Maharashtra, between February 2022 and January 2025. The region is characterized by semi-arid climatic conditions, with monsoon-dependent rainfall and soils ranging from black cotton to lateritic types. Selected study sites included croplands, orchards, fallow lands, and semi-natural field margins to capture habitat heterogeneity.

Sampling and Collection: Collection trips were carried out fortnightly during the early morning hours (06:00–09:00). At each selected site, a 100 m transect was established with five sampling points at 20 m intervals. Millipedes were collected using an intensive hand-picking method from diverse microhabitats, including leaf litter, upper soil strata, dead wood, debris, rock crevices, grass cover, compost heaps, and moist soils. An “L”-shaped iron tool was used to lift stones and debris, while specimens were handled carefully with sterilized forceps and gloved hands to minimize stress. Collected specimens were placed in 400 ml airtight plastic jars containing moistened moss and soil to maintain humidity during transport. Jar lids were punctured to ensure ventilation. In the laboratory, individuals were rinsed with distilled water and preserved in 75% ethanol. Representative specimens were photographed using a Sony DSC-W800/BC digital camera for documentation.

Identification of Specimens: Specimens were dissected, and diagnostic morphological structures including mandibles, labrum, labium, gnathochilarium, antennae, eyes, Tomosvary organs, legs, gonopods, and telson—were examined under a microscope. Identification was based on standard taxonomic keys and literature (Blower, 1985; Shear, 2011; Nguyen and Sierwald, 2013) and confirmed through published species records and expert consultation (Hoffman, 1999; Golovatch and Wesener, 2016). Care was taken to avoid repeated collection of the same species in subsequent surveys.

Results And Discusssion

The study involved repeated and seasonally stratified field surveys across a variety of agricultural landscapes, including croplands under active cultivation, fruit orchards, fallow lands, and semi-natural field margins. The aim was to document species diversity, assess ecological roles, and evaluate conservation challenges faced by millipede populations in a human-modified environment.

Through meticulous sampling and identification, the survey yielded a total of eight distinct species of millipedes, representing three different orders, five families, and seven genera. This taxonomic richness highlights the presence of both cosmopolitan and habitat-specific species, indicating that Buldana district, despite being an intensively cultivated region, sustains a notable diversity of millipedes. Such findings reinforce the ecological importance of agricultural landscapes as potential refugia for soil macrofauna.

Table 4.1.1. Checklist of Millipedes from Buldana District Maharashtra (India)

Order	Family	Species Name	Authority (Year)
Polydesmida	Paradoxosomatidae	*Anoplodesmus saussurii*	(Humbert, 1865)
Polydesmida	Paradoxosomatidae	*Orthomorpha coarctata*	(De Saussure, 1860)
Polydesmida	Paradoxosomatidae	*Oxidus gracilis*	(Koch, 1847)
Polydesmida	Xystodesmidae	*Harpaphe haydeniana*	(Wood, 1864)
Polydesmida	Polydesmidae	*Polydesmus* sp.	(Latreille, 1802)
Spirobolida	Trigoniulidae	*Trigoniulus corallinus*	(Gervais, 1842)
Spirobolida	Pachybolidae	*Xenobolus carnifex*	(Fabricius, 1775)
Julida	Julidae	*Julus terrestris*	(Linnaeus, 1758)

A prominent pattern observed in this study was the coexistence of widespread, disturbance-tolerant taxa alongside habitat-sensitive species. Cosmopolitan species such as *Anoplodesmus saussurii*, *Orthomorpha coarctata*, *Oxidus gracilis*, *Trigoniulus corallinus*, and *Xenobolus carnifex* were frequent across croplands, compost heaps, and organic-rich soils. These taxa are known for their ecological plasticity and ability to thrive under human-modified conditions, as also reported from Maharashtra (Patne *et al.*, 2024a; Deshmane, 2020) and the Western Ghats (Patil *et al.*, 2018). Their persistence highlights the role of generalist decomposers in maintaining decomposition and nutrient cycling in disturbed habitats.

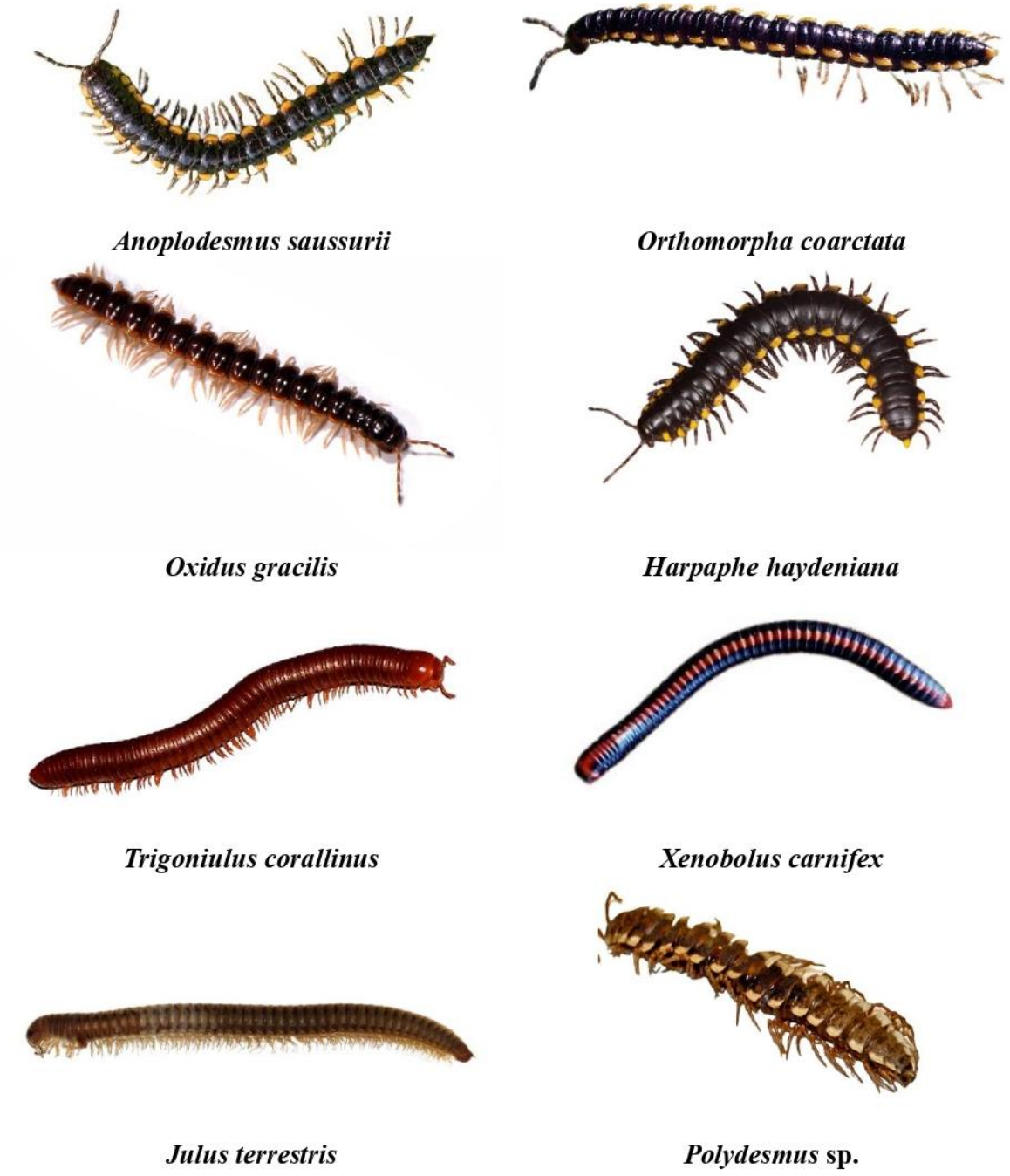

Figure 1: The millipedes of Buldana Distrct, Maharashtra (India)

In contrast, species such as *Harpaphe haydeniana* and *Julus terrestris* were recorded only from semi-natural margins, fallow lands, and litter-rich patches, suggesting their narrow ecological preferences. Such species have been identified as bioindicators of habitat quality, as their presence is often linked with relatively undisturbed microhabitats (Thakare and Kakde, 2022). Comparable patterns have been reported in Tirunelveli (Usha *et al.*, 2021) and the Sirumalai Hills of Tamil Nadu (Ramanathan *et al.*, 2023), where sensitive taxa were restricted to semi-natural habitats, while cosmopolitan species dominated cultivated lands. This contrast emphasizes the importance of conserving microhabitat heterogeneity within agricultural landscapes.

Seasonal dynamics were also a defining feature of millipede assemblages in Buldana district. Peak abundance during the monsoon and immediate post-monsoon seasons coincided with elevated soil moisture and organic matter availability, conditions favorable for detritivorous activity. Declines during the summer months, linked to desiccation stress, mirror patterns observed in Marathwada (Patne *et al.*, 2024a) and Cameroon rainforests (Makon *et al.*, 2025), where millipede populations tracked seasonal fluctuations in litter input and soil conditions. These results underscore the close coupling between millipede life cycles and climatic regimes in tropical agroecosystems.

The ecological significance of millipedes extends far beyond their diversity. By fragmenting organic matter, stimulating microbial decomposition, and improving soil aeration and water retention, they contribute to soil fertility and resilience (Patne *et al.*, 2024b; Chakraborty, 2018). The decline or loss of millipede populations under intensive farming practices—through pesticide use, litter removal, or residue burning—poses risks to these ecosystem services. Studies from Maharashtra (Deshmane, 2020; Rodge *et al.*, 2022) and southern India (Usha *et al.*, 2021) have similarly highlighted how unsustainable agricultural practices can alter millipede assemblages and reduce their ecological functioning.

From a conservation perspective, the findings reaffirm the need to integrate biodiversity-friendly practices into agricultural management. Maintaining litter-rich margins, reducing chemical inputs, and avoiding residue burning are practical measures that can enhance millipede diversity and sustain soil health. Such strategies not only benefit habitat-sensitive species but also strengthen the functional contributions of generalist taxa, ultimately promoting ecosystem stability and long-term agricultural sustainability.

Conclusion

Hence, the diversity recorded in Buldana district underscores that agricultural landscapes, when managed sustainably, can function as refugia for millipede communities. The coexistence of cosmopolitan and sensitive species reflects both resilience and vulnerability within these assemblages. Ensuring the persistence of such biodiversity is not merely an ecological imperative but also a cornerstone of maintaining soil fertility, food security, and sustainable land use in the region.

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