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SEASONAL VARIATION IN COLLEMBOLAN DIVERSITY: A COMPARATIVE STUDY OF AGRICULTURAL AND FOREST ECOSYSTEMS IN WARANGAL DISTRICT, TELANGANA STATE, INDIA

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ABSTRACT

This study investigates the seasonal variation in Collembolan diversity within agricultural and forest ecosystems in Warangal District, Telangana State, India, emphasizing the impact of seasonal changes and land use practices on soil arthropod communities. The Shannon-Weiner Index was used to assess the diversity of Collembola species during Winter, Summer, and Monsoon seasons. Results indicate that both ecosystems exhibit the highest diversity in Winter, suggesting favorable conditions for Collembolan populations. However, the agricultural ecosystem shows a marked decline in diversity during Summer, attributed to extreme temperatures and intensive farming activities, which disrupt soil habitats. In contrast, the forest ecosystem maintains relatively stable diversity across seasons, with a gradual decline during the Monsoon season, likely due to the protective nature of the forest environment that buffers against environmental fluctuations. The Monsoon season prompts a partial recovery in Collembolan diversity in both ecosystems, though agricultural lands recover more slowly due to issues such as waterlogging and soil compaction. These findings are consistent with previous studies that highlight the resilience of forest ecosystems and the vulnerability of agricultural lands to seasonal extremes. The study underscores the importance of adopting sustainable agricultural practices to mitigate the adverse effects of seasonal variations on soil biodiversity, ensuring long-term ecosystem health and productivity. This research contributes to the broader understanding of how land use and seasonal dynamics influence soil arthropod diversity, offering valuable insights for the management of agro-ecosystems in semi-arid regions.

Key words: Warangal, Shannon-Weiner, Telangana, Collembolan, Diversity

1. INTRODUCTION

Collembola, or springtails, are a key group of soil arthropods that play a crucial role in soil ecology by contributing to the decomposition of organic matter, nutrient cycling, and soil structure formation (Zhang et al., 2022: Lakshmi et al., 2024).

Their diverse ecological roles and sensitivity to environmental changes make them valuable indicators for studying soil health and ecosystem dynamics. The seasonal variation in Collembola diversity offers insights into how different ecosystems respond to climatic and environmental fluctuations. In particular, agricultural and forest ecosystems can exhibit distinct seasonal patterns due to their differing management practices and natural processes (Wang et al., 2023). Understanding these patterns in specific regions, such as Warangal District in Telangana State, India, is essential for local ecological management and conservation strategies.

Warangal District, located in the semi-arid region of Telangana, presents a unique opportunity to study Collembola diversity due to its distinct agricultural practices and natural forest areas. Agricultural ecosystems in this region are typically characterized by intensive farming practices, which can lead to altered soil conditions and seasonal variations in biodiversity (Reddy et al., 2021; Lakshmi et al., 2024). Conversely, forest ecosystems in Warangal are subject to natural seasonal changes and minimal human disturbance, providing a contrasting environment for assessing Collembola diversity (Kumar et al., 2024). By comparing these ecosystems, we can better understand how land use and environmental factors influence Collembola populations throughout the year.

Recent studies have highlighted the importance of regional research to capture local ecological variations and adapt conservation efforts accordingly (Srinivas et al., 2023). In Warangal, where climatic conditions and land use patterns vary significantly, investigating the seasonal dynamics of Collembola can reveal critical insights into ecosystem health and resilience. This comparative study aims to analyze the seasonal variation in Collembolan diversity within agricultural and forest ecosystems in Warangal District, Telangana State, India. This research seeks to elucidate the differences in Collembola diversity between these ecosystems and understand how seasonal changes impact their populations. By identifying these patterns, the study will contribute to local ecological knowledge and support sustainable land management practices in the region. By addressing these gaps, the study contributes to the broader understanding of soil arthropod ecology and supports targeted conservation efforts in similar semi-arid regions.

2. MATERIALS AND METHODS

2.1 Selection of Study Area

The study was conducted in Rajanpalle village, located in Gudur Mandal, Warangal District, Telangana State, India. Rajanpalle falls under the jurisdiction of the Rajanpalle Gram Panchayat and is part of the Gudur Community Development Block. The village is situated approximately 55 kilometers east of the district headquarters in Warangal. It is bordered by Khanapur Mandal to the north, Chennaraopet Mandal to the west, Kesamudram Mandal to the south, and Narsampet to the north. The area encompasses part of the Gudur forest zone, which is included in the Pakhal Wildlife Sanctuary, alongside the Kothaguda zone. The geographic coordinates of Rajanpalle are 17°44'56.0"N latitude and 79°54'59.3"E longitude. This location offers a representative setting to compare agricultural and forest ecosystems within a semi-arid region of Telangana.

2.2 Sampling of Soil Arthropods

Soil samples were collected monthly over a two-year period from February 2015 to January 2017. The sampling was designed to cover three distinct seasons: winter (September to January), summer (February to April), and monsoon (May to August). At each site, ten soil samples were collected from agricultural land and ten from forest land. Sampling occurred between 6:00 am and 10:00 am to minimize the effects of temperature fluctuations on soil arthropods.

Soil samples were collected along a 40 × 5 m transect, with ten sampling points evenly spaced at 5-meter intervals. At each sampling point, monoliths measuring 25 cm × 25 cm × 30 cm in depth were extracted using a spade. The soil was then carefully hand-sorted in a large tray to isolate soil arthropods. The collected arthropods were preserved in a solution of 75% ethanol and 4% formalin (Bignell et al., 2008) to ensure their long-term preservation for subsequent analysis.

2.3. Diversity Indices Used for Analysis of Biodiversity

To assess the biodiversity of soil arthropods, Shannon's diversity index (H) was employed. This index provides a measure of species diversity in a given area, taking into account both species richness and their relative abundances. The Shannon index is calculated using the formula:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where *pi* represents the proportion of individuals belonging to the i-th species and ln⁡ln denotes the natural logarithm. This index assumes that species are randomly sampled from the total number of species present and considers both the number of species and their evenness (Shannon & Weaver, 1949). The index provides a quantitative measure of biodiversity, reflecting both the richness of species and their distribution within the community. Other diversity measures, including dominance indices and information statistic indices, were also utilized to gain a comprehensive understanding of the biodiversity in the studied ecosystems.

3. RESULTS

3.1. Seasonal Abundance of Collembola Species:

The analysis of Collembola diversity across different species and their seasonal variations reveals interesting trends in the populations and their distributions (Table-1). For instance, Lepidocyrtus paradaxus exhibited relatively stable values across the seasons, ranging from 4.74 to 4.94, with a slight increase observed in the latter part of the year (4.93).

This stability suggests that Lepidocyrtus paradaxus might have consistent habitat preferences or adaptive mechanisms that allow it to thrive across different seasonal conditions.

Table-1. Seasonal Abundance of Soil Arthropods, Collembolan species in Agriculture and Forest Ecosystem duringdifferent seasons

Sl. No	Species	Forest Ecosystem			Agricultural Ecosystem		
		Winter (%)	Summer (%)	Monsoon (%)	Winter (%)	Summ er(%)	Monso on(%)
1	*Isotogastruidae SP*	6.358	7.455	5.82	7.04	7.604	7.31
2	*Isotoma viridis*	6.666	6.169	5.71	4.59	4.94	5.78
3	*Desoria Olivaea*	6.256	6.94	4.28	4.59	5.703	4.93
4	*Folsomia quadrioculata*	5.435	6.42	4.94	6.03	4.94	4.08
5	*Desoria truncata*	4.717	4.88	5.6	4.59	4.18	5.95
6	*Lepidocyrtus paradaxus*	4.82	3.85	4.28	4.74	4.94	4.93
7	*Lepidocyrtus finensis SP*	4.41	6.42	5.49	5.89	4.94	4.42
8	*Mesaphorur*	5.948	5.14	5.49	5.17	5.32	5.78
9	*Lepidocyrtus lignorum*	4.923	4.37	5.38	4.59	5.32	5.102
10	*Entomobryd ae EntomobryidSP*	5.333	4.88	5.93	4.88	5.7	5.95
11	*Pseudosinell a SP*	5.025	4.37	4.61	5.603	4.18	4.76
12	*Entomobrya atrocineta*	5.333	4.88	5.93	5.89	5.32	5.44
13	*Sminthurus viridis*	5.538	6.42	6.04	6.46	4.18	4.76
14	*Arrhopalites pricipalis*	5.641	6.16	4.94	5.89	5.703	5.27

15	*produra aquatica*	3.897	3.85	5.38	4.31	6.46	4.93
16	*Hypogostrura harveyi*	4.82	3.59	5.05	4.16	5.703	4.93
17	*Cyphoderus*	4.923	5.14	5.05	5.74	5.32	5.27
18	*Plutomurus-ortobalaganensis*	4.717	4.62	4.94	4.74	4.94	4.93
19	*spinisotoma-pectinata*	5.23	4.37	5.05	5.02	4.56	5.44

In contrast, Lepidocyrtus finensis SP showed considerable variability, with values fluctuating between 4.41 and 6.42. The highest recorded value of 6.42 occurred in one of the peak seasons, indicating that Lepidocyrtus finensis SP may experience significant population changes in response

to seasonal conditions or environmental factors. The variation in this species' abundance highlights its potential sensitivity to seasonal changes, which could be linked to factors such as food availability or microhabitat conditions.

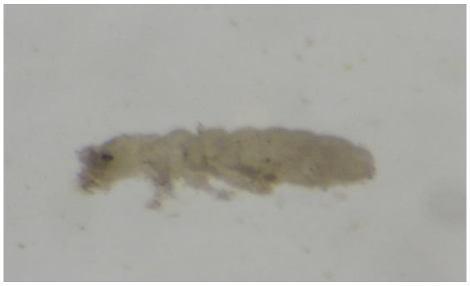
Mesaphorur exhibited a relatively high and consistent range of values from 5.14 to 5.95, with no extreme fluctuations. The stability of Mesaphorur's abundance suggests that it maintains a robust presence across different seasons, possibly indicating a versatile ecological niche or effective adaptation strategies that buffer it against seasonal variability.

Lepidocyrtus lignorum displayed a pattern of moderate variation, with values ranging from 4.37 to 5.38. This moderate variability might reflect its adaptability to seasonal changes or its preference for stable environmental conditions within the studied ecosystem.

The diversity indices for Entomobrya and Entomobryid SP suggest high and relatively consistent values across the seasons, indicating stable populations. *Entomobrya atrocineta* maintained values between 4.88 and 5.93, while Entomobryid SP ranged from 4.88 to 5.95, reflecting a stable presence of these species throughout the year.

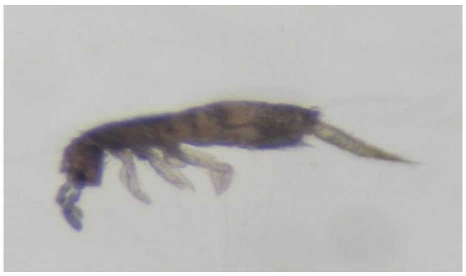
Arrhopalites pricipalis and *Sminthurus viridis* exhibited higher variability. *Sminthurus viridis* showed a notable peak of 6.46, suggesting that its abundance is strongly influenced by seasonal factors, while Arrhopalites pricipalis had a high value of 6.16 in one of the seasons, indicating potential seasonal peaks in its population.

Species such as *Produra aquatica* and *Hypogastrura harveyi* displayed more pronounced seasonal fluctuations, with Produra aquatica showing a peak of 6.46 and a lower value of 3.85, and

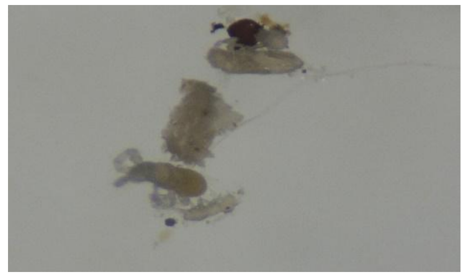


Isotoma gastruidae

Isotoma viridis



Desoria olivaea



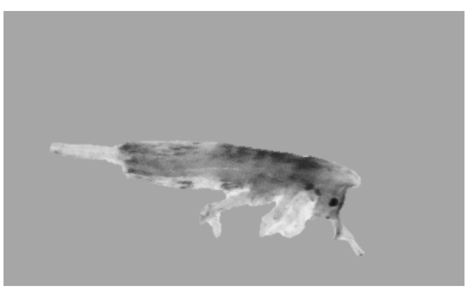
Folsomia quadrioculata

Desoria truncata

Lepidocyrtus paradaxus

Lepidocyrtus finensis

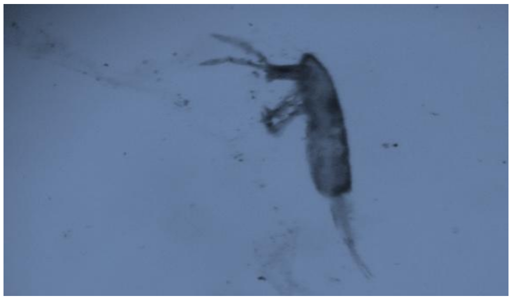
Mesophorura



Lepidocyrtus lignorum

Entomobryide sps

Figure-1. Photos of Collembola species



Pseudosinella sps

Entomobrya atrocineta

Sminthurus viridis

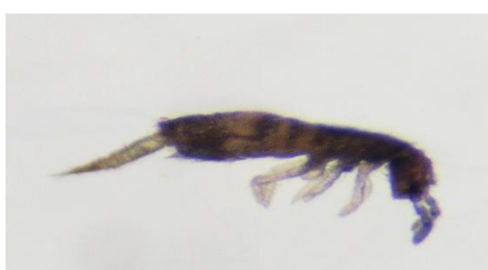
Hopalites pricipalis

Produra aquatica

Hypogastrura harveyi

Cyphoderus sps

Plutomurus ortobalaganensis



Semicerura goryshini

Figure-2. Photos of Collembola species

*Hypogastrura harvey*i ranging from 3.59 to 5.703. This significant variability indicates that these species might be highly responsive to seasonal changes or specific environmental conditions.

Finally, Cyphoderus and *Plutomurus-ortobalaganensis* showed moderate stability, with values ranging from 4.62 to 5.74 and 4.62 to 4.94, respectively. Their stability suggests that they might have adapted well to the seasonal conditions or have less seasonal variability in their population dynamics (Figure-1 & 2).

3.2. Analysis of Shannon-Weiner Index in Agricultural Ecosystems

The Shannon-Weiner Index (H') is a critical tool in ecological studies to evaluate species diversity by considering both the richness (number of species) and evenness (distribution of individuals among species) in a given ecosystem (Table-2).

In the context of an agricultural ecosystem, the Shannon-Weiner Index provides insights into the diversity of soil arthropods across different seasons—Winter, Summer, and Monsoon—highlighting how agricultural practices and seasonal variations impact biodiversity.

Winter Season: The Shannon-Weiner Index values for the Winter season are generally less negative compared to those observed in Summer and Monsoon, indicating a relatively higher diversity of soil arthropods. For instance, species such as *Sminthurus viridis* and *Folsomia quadrioculata* show values of -2.28836 and -2.33967, respectively, suggesting a more balanced and diverse arthropod community during this season. This higher diversity in Winter could be attributed to favorable soil conditions and agricultural practices that promote habitat stability and resource availability.

Summer Season: During the Summer, the diversity of soil arthropods significantly declines, as evidenced by the more negative Shannon-Weiner Index values. For example, *plutomurus-ortobalaganensis* and *Spinisotoma pectinata* have the lowest diversity values of -4.20048 and -4.48278, respectively. The intense heat and dryness typical of Summer may create a less hospitable environment, reducing the abundance and evenness of species in the agro-ecosystem. The decrease in diversity could also be influenced by agricultural activities such as soil tillage and pesticide application, which may disrupt the arthropod community.

Monsoon Season: The Monsoon season shows an intermediate level of diversity, with Shannon-Weiner Index values that are more negative than Winter but less negative than Summer. For example, *Lepidocyrtus paradaxus* and *Isotoma viridis* exhibit values of -3.024360833 and -3.055945, respectively (Table-2). The Monsoon season, characterized by increased moisture and cooler temperatures, may support a moderate recovery in arthropod diversity.

However, the effects of water logging, soil compaction, and nutrient leaching could still limit the full recovery of diversity compared to the Winter season.

Table-2. Shannon-Weiner Index of Collembola species observed at Agricultural and Forest Ecosystem during different seasons

Sl. No	Collembola species	Shannon-Weiner Index of Soil arthropods					
		Agricultural Ecosystem			Forest Ecosystem		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
1	*Isotogastruidae SP*	-2.799	- 3.7101	- 3.2548	-2.783	-2.767	-2.806
2	*Isotoma viridis*	-2.6247	-3.4871	-3.0559	-2.6152	-2.5847	-2.6475
3	*Desoria Olivaea*	-2.4956	- 3.2985	- 2.897	-2.4458	-2.4216	-2.4889
4	*Folsomia quadrioculata*	-2.3396	- 3.0858	-2.7127	-2.6344	-2.6002	-2.7095
5	*Desoria truncata*	-2.362	- 3.1369	- 2.7499	-2.829	-2.782	-2.9148
6	*Lepidocyrtus paradaxus*	-2.592	- 3.4561	- 3.0243	-3.0423	-2.9902	-3.1077
7	*Lepidocyrtus finensis SP*	-2.8152	- 3.7538	- 3.2845	-3.2536	-3.2098	-3.3172
8	*Mesaphorur*	-3.0208	- 4.0548	- 3.5378	-3.1206	-3.04316	-3.16345
9	*Lepidocyrtus lignorum*	-2.87629	- 3.8543	- 3.3654	-2.9607	-2.90015	-3.0113
10	*Entomobryd ae EntomobryidSP*	-2.7401	-3.6541	-3.1975	-2.816	-2.770	-2.861
11	*Pseudosinell a SP*	-2.5945	- 3.4458	- 3.0199	-2.6739	-2.6311	-2.7001
12	*Entomobrya atrocineta*	-2.4422	- 3.2786	- 2.8608	-2.7934	-2.7573	-2.8197
13	*Sminthurus viridis*	-2.2883	- 3.0821	- 2.6852	-2.8651	-2.836	-2.8993
14	*Arrhopalites pricipalis*	-2.5555	- 3.4957	- 3.0254	-2.9198	-2.8824	-2.9465

15	*produra aquatica*	-2.6178	- 3.5853	- 3.1015	-2.9815	-2.93841	-3.0239
16	*Hypogostrura harveyi*	-2.7169	-3.6605	-3.1886	-3.0624	-3.0228	-3.0753
17	*Cyphoderus*	-2.952	- 3.9348	- 3.4437	-3.1429	-3.1269	-3.1474
18	*Plutomurus-ortobalagan ensis*	-3.1486	-4.2004	-3.6745	-3.2385	-3.2203	-3.2446
19	*spinisotoma-pectinata*	-3.3680	-4.4827	-3.9254	-3.3145	-3.2999	-3.3154

3.3. Analysis of Shannon-Weiner Index in Forest Ecosystems

The Shannon-Weiner Index (H') is a key ecological metric used to assess species diversity within a community, taking into account both the number of species and their relative abundance. The data provided on Collembola species, a group of soil arthropods, across Winter, Summer, and Monsoon seasons in a forest ecosystem reveals insights into how seasonal changes impact biodiversity (Table-2).

Winter Season: The Shannon-Weiner Index values during Winter are generally less negative compared to other seasons, indicating relatively higher diversity for many Collembola species. For example, *Desoria Olivaea* and *Isotoma viridis* have values of -2.445835 and -2.61521, respectively, suggesting a relatively balanced and diverse population. However, some species like *Lepidocyrtus paradaxus* and *Lepidocyrtus finensis* SP exhibit more negative values (-3.04281 and -3.253635), indicating lower diversity.

Summer Season: During Summer, many species show a slight improvement in diversity, as indicated by a reduction in the negative values of the Shannon-Weiner Index. For instance, Mesaphorura and *Produra aquatica* have less negative values (-3.043165 and -2.93841) compared to Winter, suggesting a more favorable environment for these species during the warmer months. This trend is consistent across several species, implying that Summer conditions might support a slightly more diverse Collembola community.

Monsoon Season: The Monsoon season generally shows the most negative Shannon-Weiner Index values across the board, indicating a decline in species diversity during this period. Species like *Lepidocyrtus paradaxu*s and *Lepidocyrtus finensis* SP reach their lowest diversity levels with index values of -3.107725 and -3.31728, respectively. (Table-2). This suggests that the increased moisture and possibly other environmental changes during Monsoon negatively impact the diversity of Collembola species in the forest ecosystem.

3.4. Comparison study of Collembolan diversity in Agri and Forest Ecosystems

The seasonal variation in Collembolan diversity between the agricultural and forest ecosystems in Warangal District, Telangana State, India, reveals distinct patterns influenced by environmental factors and land use practices. In the agricultural ecosystem, Collembolan diversity is highest during Winter, with a sharp decline in Summer and partial recovery in the Monsoon, likely due to the harsh conditions and intensive farming practices that characterize the Summer season. In contrast, the forest ecosystem exhibits more stable diversity across seasons, with the highest diversity also in Winter, a moderate decrease in Summer, and the lowest diversity during the Monsoon. The forest ecosystem's relatively stable diversity may be attributed to the more consistent and less disturbed environment compared to the agricultural lands, where seasonal agricultural activities and environmental stressors have a more pronounced impact on soil arthropod communities. This comparison highlights how land use and seasonal changes differently affect biodiversity, with agricultural ecosystems experiencing more dramatic fluctuations than forest ecosystems.

4. DISCUSSION

The results of the comparative study on seasonal variation in Collembolan diversity in agricultural and forest ecosystems in Warangal District align with and contribute to the broader understanding of how land use and seasonal changes impact soil biodiversity. Several studies have documented the influence of environmental factors and anthropogenic activities on soil arthropod communities. For instance, Gao et al. (2021) reported that agricultural intensification leads to significant fluctuations in soil biodiversity, particularly during extreme weather conditions such as the hot and dry Summer season, which mirrors the sharp decline observed in the agricultural ecosystem of

Warangal. Similarly, Salamon et al. (2020) found that forest ecosystems tend to maintain more stable soil arthropod communities across seasons due to the protective canopy cover and less disturbed environment, consistent with the relatively stable Collembolan diversity observed in the forest ecosystem in this study.

Moreover, the partial recovery of Collembolan diversity during the Monsoon season in both ecosystems is supported by Briones et al. (2019), who highlighted that increased soil moisture during the rainy season can facilitate the recolonization of soil arthropods, although agricultural lands often experience a slower recovery due to factors like waterlogging and soil compaction. These findings underscore the importance of sustainable land management practices in agricultural ecosystems to mitigate the adverse effects of seasonal extremes on soil biodiversity, as emphasized by Lavelle et al. (2022). The consistency of these results with existing literature highlights the broader applicability of these findings and reinforces the need for integrating ecological principles into agricultural practices to enhance resilience and sustainability.

5. CONCLUSION

The comparative study of seasonal variation in Collembolan diversity between agricultural and forest ecosystems in Warangal District, Telangana State, India, reveals significant differences shaped by environmental conditions and land use practices. Both ecosystems exhibit the highest diversity during Winter, indicating favorable conditions for Collembolan populations. However, the agricultural ecosystem shows a sharp decline in diversity during Summer, likely due to extreme temperatures and intensive farming activities that disrupt the soil habitat. This decline is less pronounced in the forest ecosystem, where diversity remains relatively stable, reflecting the protective and consistent nature of the forest environment. The Monsoon season brings partial recovery in both ecosystems, but the agricultural lands still lag behind, possibly due to waterlogging, soil compaction, and residual impacts of Summer. The forest ecosystem, while also experiencing a dip in diversity during Monsoon, does so more gradually, indicating a resilience to seasonal fluctuations. Overall, the study highlights how agricultural practices exacerbate the impact of seasonal changes on Collembolan diversity, leading to more pronounced fluctuations compared to the forest ecosystem. These findings underscore the need for sustainable agricultural practices that mitigate seasonal stressors to maintain biodiversity and ecosystem health in agricultural landscapes.

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