Uttar Pradesh Journal of Zoology

Volume 45, Issue 20, Page 273-283, 2024; Article no.UPJOZ.4190
ISSN: 0256-971X (P)

The Impact of Plant Diversity on Spider Populations in a Tropical Butterfly Conservatory, Tiruchirappalli, South India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i204584

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4190

Original Research Article

Received: 17/08/2024
Accepted: 21/10/2024
Published: 02/11/2024

ABSTRACT

Spiders, as crucial predators and biodiversity indicators, significantly influence ecosystem health. This study investigates the intricate relationship between plant diversity and spider communities within distinct habitats of the Tropical Butterfly Conservatory, Tiruchirappalli, India. By classifying spiders based on their hunting strategies, we aim to understand their ecological roles. This research establishes a baseline for the spider fauna within the conservatory, emphasizing the impact of plant life on spider diversity and distribution. Our findings contribute to a comprehensive evaluation of the ecological importance of spiders in this unique ecosystem, providing valuable insights for future conservation and management efforts. By unravelling the complex interplay between plants and spiders, this study underscores the necessity of preserving plant diversity to sustain a robust and balanced spider community.

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Cite as: *Gayathri, M V, and Horne Iona Averal. 2024. "The Impact of Plant Diversity on Spider Populations in a Tropical Butterfly Conservatory, Tiruchirappalli, South India". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (20):273-83. https://doi.org/10.56557/upjoz/2024/v45i204584.*

Keywords: Spiders; plant diversity; plant-spider interactions; ecosystem health; biodiversity conservation; tropical butterfly conservatory; Tiruchirappalli.

1. INTRODUCTION

Recent studies have elucidated the intricate relationship between plant characteristics and spider communities. (Schuldt et al., 2018) emphasized the multifaceted role of plant diversity, encompassing species richness, structural complexity, and functional attributes, in shaping consumer biodiversity. While (Mendieta-Leiva et al., 2018), (Melliger et al., 2018) focused on the influence of epiphytic plant characteristics, such as isolation, spatial arrangement, and size, on spider community composition, independent of plant diversity, other studies have directly linked plant diversity to spider abundance and richness.

(Potapov et al., 2019) highlighted the detrimental effects of habitat degradation on ground spider functional diversity and associated ecosystem services in tropical landscapes. (Kapilkumar et al., 2019) investigated the impact of invasive milkweed on spider functional diversity in pine and poplar plantations, demonstrating varying effects based on plantation type. (Da Silva Bomfim et al., 2021) explored the positive influence of rosette-shaped plants on spider diversity and functional traits in grasslands under different grazing regimes. (Butz et al., 2023) demonstrated the positive correlation between tree diversity and arboreal spider abundance, mediated by increased canopy cover in diverse plots. (Ávila et al., 2017) emphasized the importance of habitat heterogeneity in determining spider diversity within pond ecosystems, with more diverse habitats supporting higher spider abundance and species richness. (Esquivel-Gómez et al., 2017) found that tree species diversity in tropical forest plantations positively impacted weaver spider abundance, richness, and diversity. (Junggebauer et al., 2021) revealed the negative consequences of rainforest conversion to monoculture plantations on plant and phylogenetic diversity of jumping spider communities. (Quijano-Cuervo et al., 2024) investigated the interactive effects of plant diversity, landscape composition, and agricultural cycle stages on spider guild richness and abundance in maize polycultures.

Earlier studies have also contributed significantly to understanding the spider-plant relationship. (Theron et al., 2020), (Lafage et al., 2018) underscored the importance of diverse vegetation structures, including remnant patches and shrub layers, in promoting spider diversity. (Griotti et al., 2017) highlighted the complex interplay between habitat type and vegetation structure in shaping spider assemblages. (Zheng et al., 2017) compared spider species composition between natural forests and plantations, emphasizing the role of canopy cover and understory vegetation.

(Gayathri et al., 2022) explored the Spiders are key components of all ecosystems in which they live and considered to be useful indicators of the overall species richness, health of terrestrial communities, Natural Pest Control, Good friend of Farmers. Arachnida population in the tropical butterfly conservatory, Tiruchirappalli. Sivakumar et al., 2024 compares spider diversity, web types, and prey capture in two Coimbatore localities, revealing higher diversity in Site A (Semmedu) based on multiple diversity indices.Singh et al., 2023 provides an updated catalogue of 547 spider species across 46 families in Tamil Nadu, India, with the highest diversity found in Nilgiris, Salem, and Coimbatore districts.

Web-building spiders, especially in the genus Eustala, exhibit host plant specificity and associations with certain plant species (Hesselberg et al., 2023). Plant diversity positively influences spider species richness, diversity, and community organization in a calcareous fen habitat (Štokmane et al., 2016). Spider communities are influenced by both prey availability and habitat structure, which are affected by deer herbivory and invasive plants (Landsman et al., 2017). The paper discusses how plant diversity affects insect herbivores and their natural enemies, but does not specifically address the role of plant diversity in spider assemblage formation (Moreira et al., 2016). Native plant diversity around greenhouses can promote spider communities that provide biological control of horticultural pests (Cotes et al., 2018).

These findings collectively underscore the critical role of plant diversity and vegetation structure in structuring spider communities across diverse ecosystems within the Tropical Butterfly Conservatory (Butterfly Park) in Tiruchirappalli, India. By exploring the composition and distribution of plant diversity and spider assemblages within this unique habitat, we aim to elucidate their contribution to the park's ecological balance and their significance within the broader context of insect diversity conservation.

2. MATERIALS AND METHODS

2.1 Study Area

The Tropical Butterfly Conservatory (Butterfly Park) in Tiruchirappalli, Tamil Nadu, India as shown in Fig. 1., is one of Asia's largest, encompassing 35 acres within the Upper Anaicut Reserve Forest, flanked by the Cauvery and Kollidam rivers (78.637202° N, 10.877862° E). This biodiverse haven boasts 298 plant species, fostering a rich fauna including 125 butterflies, 101 birds, 13 dragonflies, and a remarkable assemblage of spiders (this study's focus). Additionally, the park harbours 10 mammal species, 20 reptile species, and 6 amphibian species. Notably, the Nakshatravanam and Rasivanam sections feature 27 and 12 plant species corresponding to the 27 stars and 12 zodiac signs of Indian astrology, respectively, promoting a unique cultural connection to nature. The park experiences cooler temperatures compared to the surrounding city. This study investigates the spider fauna diversity within distinct habitats of the Butterfly Park. Spider specimens were collected throughout the study period from various designated zones within the park using established sampling methods (details provided in subsequent sections).

2.2 Visual Search for Spider Collection

Spiders were collected using a direct visual search method, also known as hand collection as shown in Fig. 2. This method involved actively searching for spiders and their various life stages (eggs, juveniles, adults) within their natural habitats. Potential hiding spots included flowers, folded leaves, and undersides of leaflets, ground litter, shrubs, and tree bark. Specimens were gently driven into dry containers for capture. Notably, web-building species were primarily collected in the early morning hours when their webs were most conspicuous. This approach necessitates keen observation skills for successful spider detection.

2.3 Foliage Dislodgement with Inverted Umbrella

A complementary sampling method employed an inverted umbrella. This technique involved positioning the open umbrella beneath flowering plants and shrubs. Branches were then vigorously shaken, dislodging spiders and other invertebrates onto the umbrella's canopy. Subsequently, spiders were carefully separated from the debris and transferred to collecting vials for further analysis.

Fig. 1. Study Area - GIS Image of the Tropical Butterfly Conservatory, Melur, Tiruchirappalli, Tamilnadu
(Photo Courtesy: Google Maps)

Fig. 2. Various spider species found within Tropical Butterfly Conservatory, Tiruchirappalli

2.4 Kerchief Interception for Mobile Spider Capture

This method targeted mobile spider families like Lycosidae (wolf spiders) and Salticidae (jumping spiders). An open kerchief was swiftly deployed to envelop the running spider. The kerchief's folds then facilitated the safe capture of the specimen.

2.5 Sweep Netting for Ground-Dwelling Spiders

A sweep net proved to be an efficient tool for capturing ground-dwelling spiders. This method targeted habitats rich in grasses and flowers. The net was swept repeatedly across the vegetation until a satisfactory sample size was obtained. Captured spiders were promptly collected from the net to prevent escape. Morphological details were documented using a stereo zoom microscope for smaller specimens, while larger individuals were photographed with a D3100 camera.

A comprehensive assessment of plant diversity within the Tropical Butterfly Conservatory in Tiruchirappalli was undertaken. To quantify and compare the variety of plant life present, four standard ecological indices were utilized: Shannon's index, Simpson's index, Margalef's index, and species evenness index. Based on the following equations, statistical comparison of plant diversity across zones in the TBC, Tiruchirappalli, is calculated as shown in Table 1.

1. Shannon's index (H): $\boldsymbol{H} = -\boldsymbol{\Sigma}\,(\boldsymbol{\pi} * \ln(\boldsymbol{\pi}))$

Where,

- π is the proportion of individuals in the i^{th} species.
- ln is the natural logarithm

2. Simpson's index (D): $\boldsymbol{D} = \boldsymbol{\Sigma}\,(\boldsymbol{\pi}^2)$

Where,

- π is the proportion of individuals in the ith species.

3. Margalef's index (d): $\boldsymbol{d} = \frac{(S-1)}{ln(N)}$

Where,

- S is the total number of species.
- N is the total number of individuals.

4. Species evenness index (J): $\boldsymbol{J} = \frac{H}{ln(S)}$

Where,

- H is Shannon's index
- S is the total number of species

These metrics offer distinct perspectives on species richness, abundance, and distribution within an ecosystem. By employing these indices, detailed profile of plant diversity in the conservatory is constructed. The data collected through meticulous field observations and subsequent laboratory analyses provided the foundation for a rigorous statistical exploration. The outcomes of this analysis are meticulously presented in Tables 1 offering a quantitative overview of the plant community's composition and structure in Zone I, II and III of Tropical Butterfly Conservatory, Tiruchirappalli.

The Tropical Butterfly Conservatory, with its unique microclimate and carefully curated plant collection, serves as an invaluable model ecosystem for studying plant diversity which caters spider assemblage. Understanding the intricacies of plant life within this environment is crucial for preserving spider biodiversity and supporting the delicate balance of the insect ecosystem.

Table 1. Statistical comparison of plant diversity across zones in the TBC, Tiruchirappalli

Zone I				
Flora	**Shannon-Weiner Index**	**Margalef's Index**	**Species Evenness Index**	**Simpson's Dominance Index**
Trees	3.51535	107.605	0.231721	0.041919
Herbs	3.11185	188.7095	0.210601	0.051257
Shrubs	3.22895	168.6248	0.214485	0.05885
Zone II				
Flora	**Shannon-Weiner Index**	**Margalef's Index**	**Species Evenness Index**	**Simpson's Dominance Index**
Trees	3.30385	69.89857	0.254228	0.047896
Herbs	3.32701	155.3387	0.163507	0.042499
Shrubs	3.35728	81.91302	0.243665	0.041237
Zone III				
Flora	**Shannon-Weiner Index**	**Margalef's Index**	**Species Evenness Index**	**Simpson's Dominance Index**
Trees	3.55381	93.24276	0.2378	0.039171
Herbs	2.8405	118.3822	0.227773	0.078796
Shrubs	3.12378	156.6864	0.217104	0.063188

3. RESULTS AND DISCUSSION

Spiders, often overlooked but undeniably crucial, play a pivotal role in maintaining ecological equilibrium. As voracious predators, they regulate insect populations, thereby contributing to ecosystem health. Additionally, their sensitivity to environmental changes makes them valuable bioindicators. This study delves into the intricate relationship between plant diversity and spider assemblages within the confines of the Tropical Butterfly Park in Trichy, India. By investigating the park's rich flora and fauna as shown in Fig. 3, researchers aimed to uncover the underlying factors influencing spider distribution and abundance.

A comprehensive survey of the park revealed a diverse spider community comprising fifteen species across five families, a testament to the park's rich ecological tapestry. The presence of spiny orb-weavers, particularly abundant in the Nakshatravanam zone, underscored the importance of tall trees as ideal habitats for web construction. Moreover, the availability of host plants and nectar sources significantly impacted the distribution of tunnel web spiders. This suggests that the parks varied habitats, characterized by distinct microclimates, diverse food resources, and suitable web attachment sites, create a conducive environment for spider proliferation.

The study further explored the influence of plant diversity on spider distribution by examining three distinct zones within the park as shown in Table 2. Zone I emerged as the botanical powerhouse, boasting the highest plant density(3266 individuals) as shown in Fig. 4. This zone was dominated by herbaceous plants, providing a dense ground cover. In contrast, Zone III(2486 individuals) as shown in Fig. 5 showcased a higher proportion of shrubs and Zone II (1988 individuals) as shown in Fig. 6, while trees remained relatively scarce across all zones. This variation in plant composition had a direct impact on spider community structure. Araneidae, renowned for their orb webs, thrived in Zone I, likely due to the presence of tall trees. Conversely, Salticidae, known for their hunting prowess, dominated Zones II and III, where a combination of old buildings, wetlands, and herbaceous vegetation created suitable conditions.

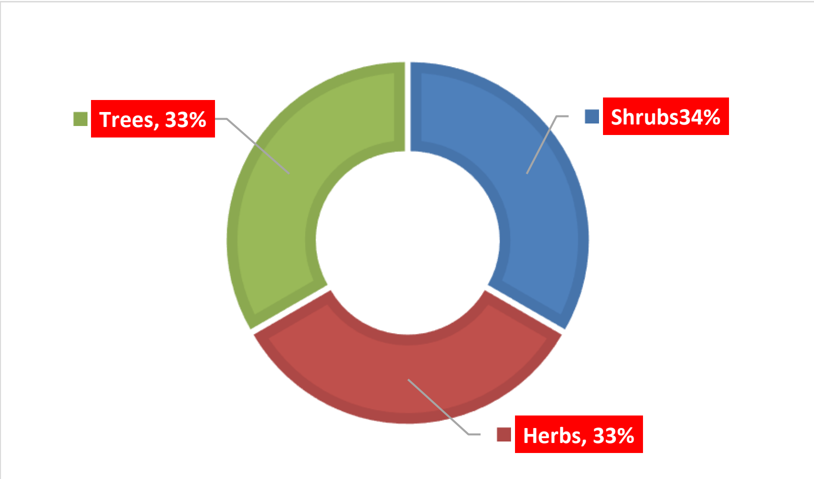

Fig. 3. Overall distribution of plant population within Tropical Butterfly Conservatory, Tiruchirappalli

Table 2. Percentage of plant population diversity in Tropical Butterfly Conservatory, Tiruchirappalli

Zone	Plant Distribution	Tree Population	%	Herbs Population	%	Shrubs Population	%	Others	Total Population
II	Plant Species	61		29		47		Least Distributed	137
	Total Population in Zone I	707	22	1363	42	1196	36		3266
II	Plant Species	41		35		37		Least Distributed	113
	Total Population in Zone II	389	19	1087	55	512	26		1988
III	Plant Species	53		23		36		Least Distributed	112
	Total Population in Zone III	597	24	791	32	1089	44		2486

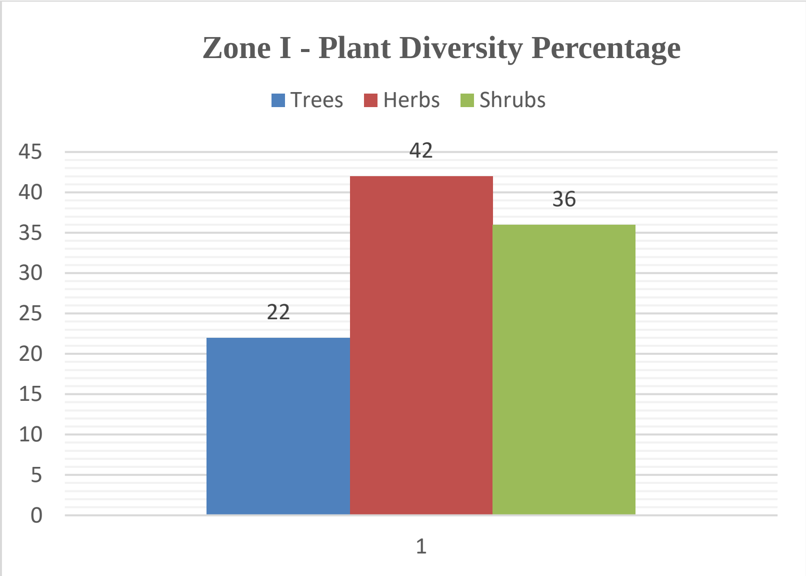

Fig. 4. Plant Diversity Distribution in Zone I of TBC, Tiruchirappalli

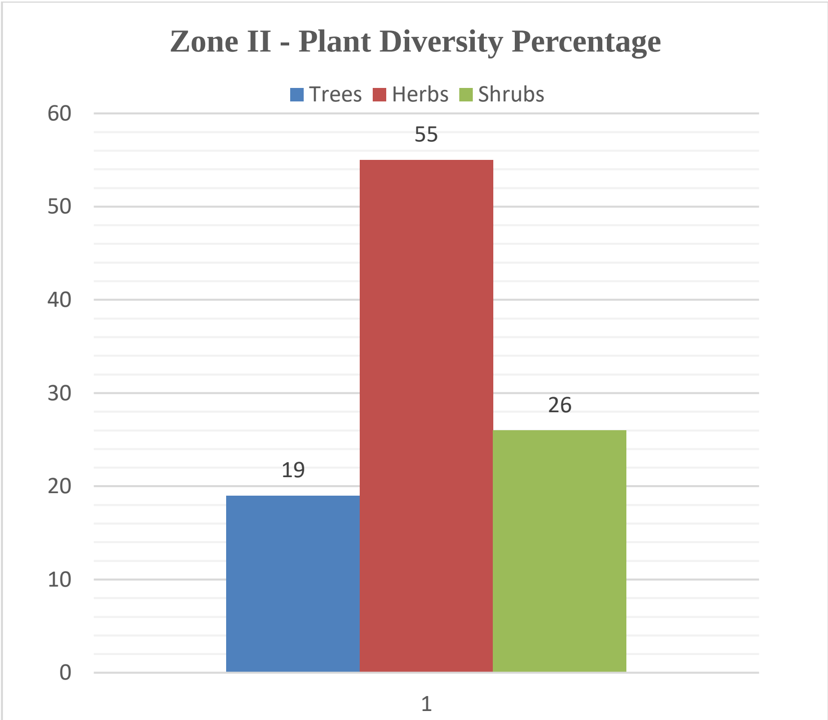

Fig. 5. Plant Diversity Distribution in Zone II of TBC, Tiruchirappalli

The observed patterns in plant distribution and spider abundance strongly suggest a link between habitat heterogeneity and species diversity. The predominance of Araneidae in Zone I highlights the importance of specific plant structures, such as tall trees, in shaping spider communities. Similarly, the prevalence of Salticidae in Zones II and III emphasizes the role of diverse ground cover and vertical structures. These findings underscore the intricate interplay between plants and spiders, with each influencing the distribution and abundance of the other.

To gain a deeper understanding of the relationship between plant diversity and spider assemblages, detailed data on plant species richness and abundance were collected.

Statistical analysis revealed significant variations in plant composition across the three zones. While Zone I excelled in terms of overall plant density, Zone III exhibited a higher proportion of shrubs. These differences in plant community structure were mirrored in the spider community, with distinct patterns of species distribution.

The results of this study as shown in Fig. 7 unequivocally demonstrate the crucial role of plant diversity in structuring spider communities. The presence of specific plant types, such as tall trees and dense ground cover, created favourable conditions for different spider families. However, the complex interplay between plants and spiders is influenced by a multitude of factors, including microclimatic conditions and prey availability.

By elucidating the factors driving spider distribution and abundance, this study contributes to our understanding of ecosystem functioning and the conservation of biodiversity. The findings emphasize the importance of maintaining habitat heterogeneity to support diverse plant and spider communities as shown in Table 2 and Fig. 8. Conservation efforts should prioritize the protection of plant species that provide critical resources for spiders, such as nectar, prey, and suitable web attachment sites.

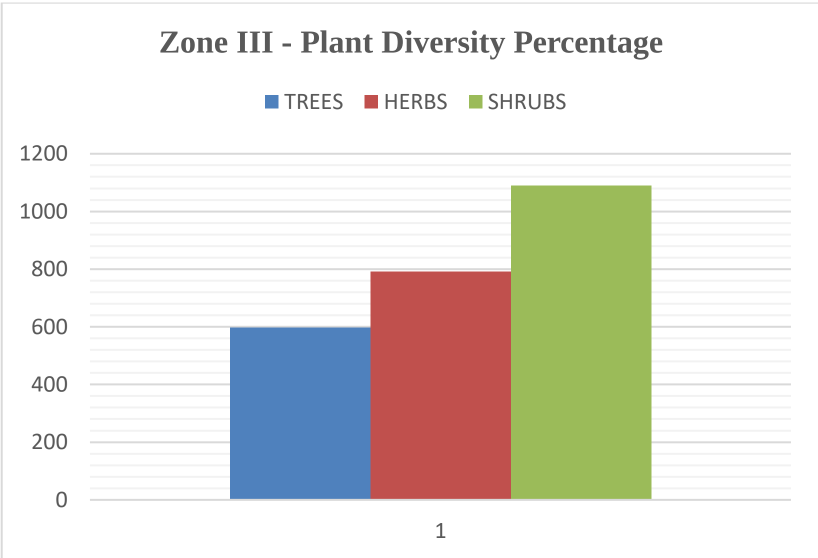

Fig. 6. Plant Diversity Distribution in Zone III of TBC, Tiruchirappalli

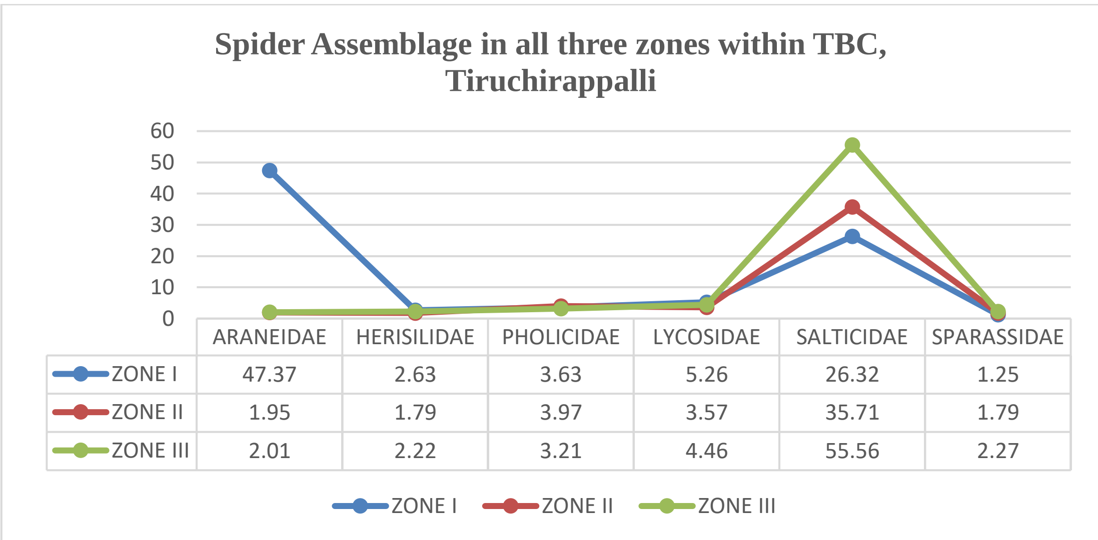

Fig. 7. Spider assemblage distribution in all the three zones within Tropical Butterfly Conservatory, Tiruchirappalli

Table 3. Family-wise spider assemblage within Tropical Butterfly Conservatory, Tiruchirappalli

Sl.No.	Family	Percentage Population
1	ARANEIDAE	25%
2	HERISILIDAE	2%
3	LYCOSIDAE	3%
4	OXYOPIDAE	16%
5	SALTICIDAE	27%
6	SPARASSIDAE	5%
7	TETRAGNATHIDAE	4%
8	THERIDIIDAE	7%
9	THOMISIDAE	14%
10	PHILODROMIDAE	3%
11	CORINNIDAE	1%
12	GNAPHOSIDAE	7%
13	PHOLICIDAE	5%

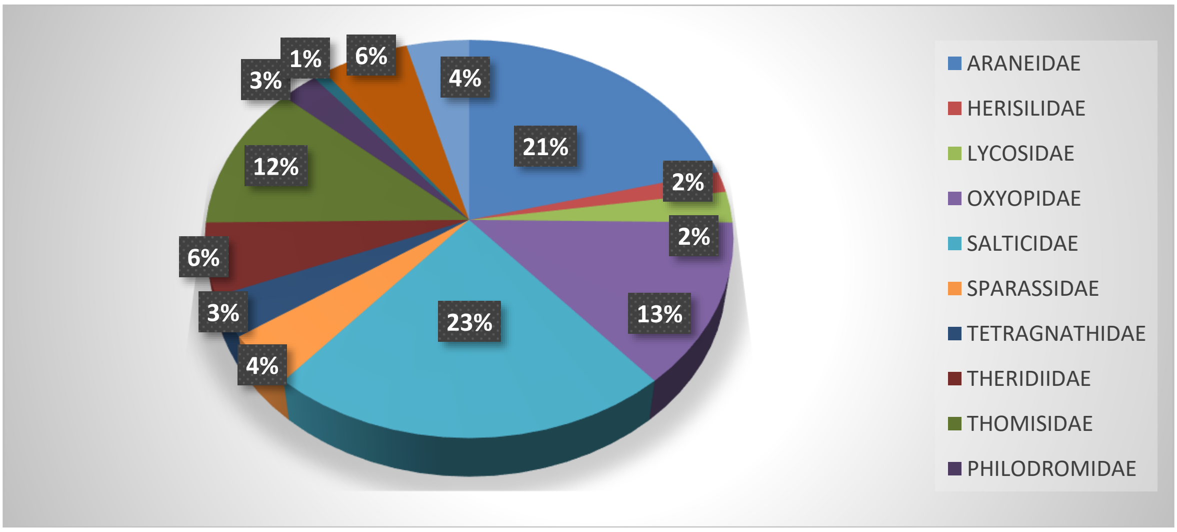

Fig. 8. Spider assemblage family-wise distribution within Tropical Butterfly Conservatory, Tiruchirappalli

To fully comprehend the ecological dynamics within the Tropical Butterfly Park, future research should focus on exploring the influence of microclimatic factors on spider distribution. Additionally, investigating the role of prey availability in shaping spider communities would provide valuable insights into the trophic interactions within this ecosystem. By combining these approaches, we can develop a more comprehensive understanding of the complex relationships between plants, spiders, and their environment.

4. CONCLUSION

The study underscore the intricate relationship between plant diversity, habitat complexity, and spider community structure. This study, in conjunction with previous research, reinforces the notion that spiders are sensitive bioindicators reflecting the overall health and resilience of an ecosystem. A diverse spider assemblage is indicative of a complex and stable environment, rich in both plant and structural resources. Therefore, meticulous documentation of spider diversity patterns can serve as a powerful tool for assessing an ecosystem's conservation priority. By elucidating the factors driving spider community composition, we can refine conservation strategies to target habitats critical for maintaining these essential ecological indicators. The research also highlights the urgent need for comprehensive studies exploring the synergistic interactions between plants, spiders, and environmental conditions to inform effective conservation practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

We gratefully acknowledge financial support from the Directorate of Collegiate Education, Chennai, Tamil Nadu, India (Grant No: 44500/L/2019), which facilitated this research. We also extend our appreciation to the Tamil Nadu Forest Department, Tiruchirappalli Division, Tamil Nadu, India for their cooperation and assistance during the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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