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Assessment of Arthropod Biodiversity in Mulberry Plants During the Summer Season

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ABSTRACT

The silkworm industry plays a crucial role in providing employment opportunities, particularly in regions like Karnataka, Andhra Pradesh, Assam, West Bengal, Jharkhand, and Tamil Nadu. This industry heavily relies on mulberry plants (*Morus alba* L.) as the primary food source for silkworms (*Bombyx mori*). The quality of mulberry leaves directly influences cocoon quality and colour, making Moriculture pivotal in sericulture. Mulberry plants face various challenges, including diseases and pest infestations, affecting leaf growth and silk quality. This study, conducted at Holy Cross College, Tamil Nadu, aims to identify and analyze arthropods damaging mulberry leaves. Arthropods from two classes, Insecta and Arachnida, were identified and classified into orders, families, and genera. Hemiptera emerged as the most diverse order among Insects. Notably, sap-sucking insects like mealy bugs, hoppers, and jassids were observed, consistent with previous research. The Shannon Weinner index, Species richness and Species evenness were found to be more in the mulberry garden as per this study. The study's findings emphasized the need for integrated pest management strategies to enhance mulberry leaf production for the sericulture industry's sustainability.

INTRODUCTION

The sericulture industry, which revolves around the production of silk, plays a significant role in providing employment opportunities in various states of India, such as Karnataka, Andhra Pradesh, Assam, West Bengal, Jharkhand, and Tamil Nadu. This agro-based industry relies heavily on the cultivation of mulberry plants (*Morus alba* L.), as the leaves of the mulberry plant serve as the primary food source for silkworms (*Bombyx mori*). The quality and colour of the silk cocoon are influenced by the quality of mulberry leaves, making mulberry cultivation, also known as Moriculture, a critical aspect of the sericulture industry. Maintaining healthy mulberry plants through regular activities like watering, fertilizing, pruning, and protection from pests and predators is vital (Sakthivel *et al*., 2019). Silk, often referred to as the "queen of textile fibres," is highly valued for its warmth, softness, and strength. While silk products are often associated with luxury, it's worth noting that the silk industry is also an essential source of employment for many people, including those from economically disadvantaged backgrounds. India, as the second-largest silk producer globally, boasts a unique position as the only country producing all major silk varieties, including Mulberry, Eri, Tasar, and Muga. Mulberry silk dominates the market, constituting about 90% of the total production (Naik AH, 2017).

However, mulberry cultivation faces several challenges, including attacks by bacteria, fungi, viruses, and nematodes that lead to various diseases in mulberry plants. Factors such as plant varieties, seasonal fluctuations, and cultivation practices further influence mulberry leaf growth, which, in turn, impacts cocoon and silk quality. Protecting mulberry plants from diseases is imperative. Additionally, mulberry plants and leaves are vulnerable to a diverse pest complex comprising different insect orders. Frequent leaf picking for silkworm feed and pruning can mitigate pest issues to some extent, but a significant pest complex often plagues mulberry plants. Notably, Lepidoptera, Hemiptera, Coleoptera, Thysanoptera, Orthoptera, and Isoptera are major insect orders known to be pests of mulberry (Sengupta, K., 1990). Mulberry leaves and fruits contain essential nutrients like Iron, Riboflavin, Vitamin C, Vitamin K, Potassium, Phosphorous, Calcium, dietary fibre, phytonutrients, and anthocyanins (Begum, N *et al*., 2018). Silkworms utilize these components to produce silk proteins. The presence of pests can impact the macro and micro-nutrient content in mulberry leaves, further affecting cocoon and silk quality (Ito, T. and Nimura, M. 1966). The common pests affecting mulberry plants fall into categories such as sap suckers, root feeders, and defoliators. Sapsuckers, which include mealy bugs, thrips, whiteflies, hoppers, jassids, and aphids, directly damage mulberry tree tissues. Among these, leaf hoppers, thrips, and aphids are particularly destructive to the crop (Fatima, A. *et al*., 2018).

Common insects found on mulberry plants belong to orders such as Coleoptera, Lepidoptera, Hemiptera, and Thysanoptera (Shanthi and Kumar, 2010). The young silkworm larvae predominantly feed on tender leaves, which are susceptible to pest infestation, causing severe damage. The incidence of pests is highest from June to February, and various weather factors, such as temperature, relative humidity, and rainfall, affect their populations (Rahmathulla, V.K. *et al*., 2012). In addressing these challenges, the scarcity of good quality mulberry leaves due to pest attacks stands out as a significant issue for silkworm farmers. The limited use of inorganic pesticides on mulberry plants, given their role as the primary food source for silkworms, contributes to the increase in pest incidence.

In Tamil Nadu, at Holy Cross College in Nagercoil, sericulture is actively practiced with the presence of a well-established mulberry garden. Students at the college utilize the leaves from this garden for their sericulture activities. However, the persistent challenge they face is the shortage of mulberry leaves. To address this issue, a study was conducted to identify the various arthropods affecting mulberry plants, including the leaves, stalks, and stems. The research aimed to understand the species diversity of these arthropods and their impact on mulberry plants. Ultimately, this project seeks to develop an integrated pest management strategy to enhance mulberry leaf yield and quality, thus supporting the sustainable growth of the sericulture industry.

MATERIALS AND METHODS

Location and Duration of the Study:

The mulberry garden of Holy Cross College (Autonomous), Nagercoil, situated in the Kanyakumari district of Tamil Nadu, with geographical coordinates at approximately 8.1560° N latitude and 77.4151° E longitude was chosen as the study area. The research was conducted over a three-month period, spanning from February 2022 to April 2022.

Experimental Design:

Within the mulberry garden, MR2 variety mulberry plants had already been cultivated. To conduct the research, a Randomized Complete Block Design (RCBD) was employed, consisting of four blocks. Each block contained 24 mulberry plants, as described by Khan *et al*., 2020. It is noteworthy that no pesticides were utilized in the garden during the course of the study.

Collection and Identification of Insects:

Data on arthropods were gathered through visual searching techniques. A thorough examination of all 24 plants within each plot was carried out to identify any attacking arthropods. This examination took place at various stages of plant growth, including the vegetative, flowering, and reproductive stages. Moreover, different parts of each plant, namely the lower, middle, and upper leaves, were selected for inspection. The underside of the leaves was meticulously examined for the presence of arthropods. Counts were conducted before 08:30 a.m. and after 3:30 p.m. to minimize the impact of adult insects' heightened mobility, as suggested by Choudhury *et al*., 2016.

For the purpose of identification, insects were compared with specimen photographs and references from the book titled "Indian Insects and Arachnids" by Meenakshi Venkatraman, published in 2000. Additionally, online resources such as "knowyourinsects.org" were consulted. The identified insects were classified up to the genus level. Data collected over the three-month period spanning February, March, and April 2022 was organized into tables and represented graphically, with categorization based on class, orders, families, and genera. The identified insects were categorized by genus level and their relative abundance was calculated (Khan *et. al*., 2020)

A. Relative abundance

Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area (Angelo and Canencia, 2016). Relative abundance was calculated:

$$\text{Relative abundance} = \frac{\text{Total no. of each species}}{\text{Total no. of all species}} x100$$

B. Measurement of Biodiversity indices

Biological diversity studies use diversity indices as indicators. The following formulae were used to calculate the diversity indices.

Shannon - Wiener index

$$H = -\sum PiLNPi$$

Where,

H’ = Shannon - Wiener index

Pi = the relative proportion (n/N) of the individual of one particular species found.

(LNPi) = The natural logarithm (LN) of the value Pi.

(Σ) = summation of the outputs with the final value multiplied by negative one (– 1) (Omaiyo and Mzungu, 2019).

Species Evenness:

$$J = \frac{H'}{\log S}$$

Where,

J = species evenness

H’ = Shannon - Wiener index

S = Number of species in the community

Species Richness:

$$\text{Species richness } R = \frac{S-1}{\text{LogN}}$$

Where,
R = Species richness
S = Number of species in the community
N = Total population of all the species (Nair *et. al*., 2017).

The data obtained for the three months of February, March and April was used for calculating the biodiversity indices of arthropods and the results were recorded.

RESULTS

The mulberry plants in the study area were divided into four separate plots. Each day, two of these plots were subjected to arthropod analysis, while the remaining two plots were analyzed on the subsequent day.

The examination of mulberry plants took place daily, with observations occurring before 8:30 a.m. and after 3:30 p.m. During these assessments, careful attention was given to various parts of the mulberry plants, including the stem, stalk, leaves, buds, and other relevant areas. Additionally, the arthropods encountered during these inspections were meticulously documented and photographed. The recorded daily counts of arthropods served as the basis for subsequent statistical analyses in the study.

Plate 1: Mulberry Garden of Holy Cross College.

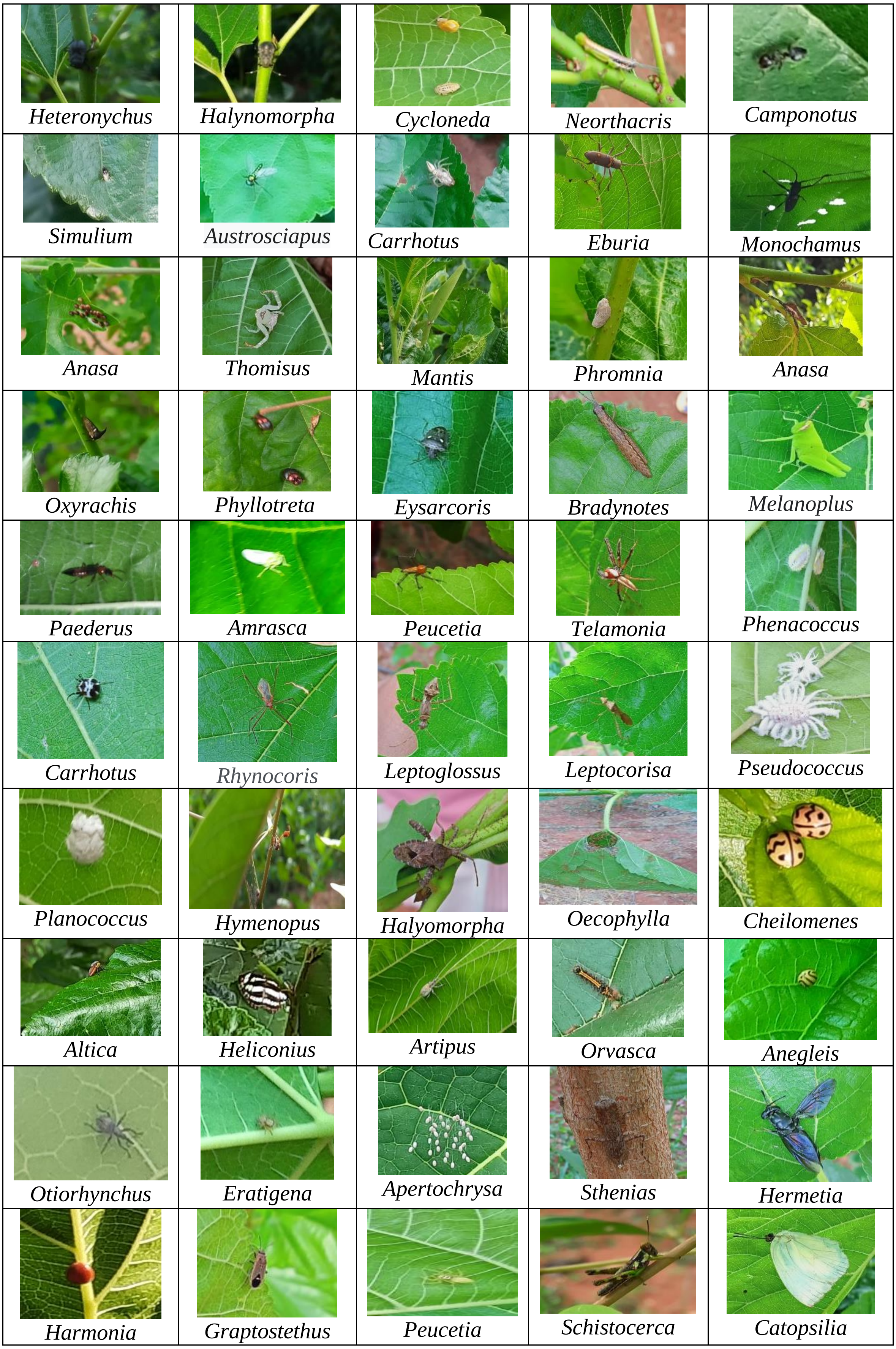


Plate 2: The Arthropods of Mulberry Plants.

. **Table 1:** List of arthropods belonging to different classes, Orders, Families and Genus

Class	*Order*	*Family*	*Genus*	**Total number (3 months)**	**Relative Abundance %**
Insecta	Coleoptera	Scarabaeidae	*Heteronychus*	22	1.72
		Coccinellidae	*Cycloneda*	34	2.66
			Cheilomenes	43	3.36
			Anegleis	32	2.50
			Harmonia	31	2.42
		Cerambycidae	*Eburia*	12	0.94
			Monochamus	16	1.25
			Sthenias	4	0.31
		Staphylinidae	*Paederus*	7	0.55
		Chrysomelidae	*Phyllotreta*	4	0.31
			Altica	2	0.16
		Curculionidae	*Artipus*	2	0.16
			Otiorhynchus	5	0.39
Insecta	Hemiptera	Pentatomidae	*Halynomorpha*	31	2.43
			Eysarcoris	12	0.94
		Coreidea	*Anasa*	38	2.97
			Leptoglossus	3	0.23
		Flatidae	*Phromnia*	3	0.23
		Membracidae	*Oxyrachis*	4	0.31
		Jassidae	*Amrasca*	1	0.08
		Reduviidae	*Rhynocoris*	20	1.56
		Alydidae	*Leptocorisa*	17	1.33
		Peseudococcidea	*Pseudococcus*	247	19.32
			Planococcus	35	2.74
			Phenacoccus	26	2.03
		Lygaeidae	*Graptostethus*	11	0.86
Insecta	Orthoptera	Pyrgomorphidae	*Neorthacris*	14	1.10
		Acrididae	*Bradynotes*	17	1.33
			Melanoplus	13	1.02
			Schistocerca	14	1.10
Insecta	Lepidoptera	Nymphalidae	Heliconius	2	0.16
		Erebidae	*Orvasca*	4	0.31
		Pieridae	*Catopsilia*	1	0.08
Insecta	Hymenoptera	Formicidae	*Gamponotus*	67	5.24
			Oecophylla	342	26.76
Insecta	Diptera	Simuliidae	*Simulium*	6	0.47
		Dolichopodidae	*Austrosciapus*	20	1.56
		Stratiomyidae	*Hermetia*	3	0.23
Insecta	Mantodea	Mantidea	*Mantis*	7	0.55
		Hymenopodidae	*Hymenopus*	1	0.08
Insecta	Neuroptera	Chrysopidae	*Apertochrysa*	28	2.19
Arachnida	Araneae	Salticidae	*Carrhotus*	2	0.16
		Thomisidae	*Thomisus*	3	0.23
		Oxyopidae	*Peucetia*	42	3.29
			Telamonia	22	1.72
		Agilenidae	*Eratigena*	8	0.63

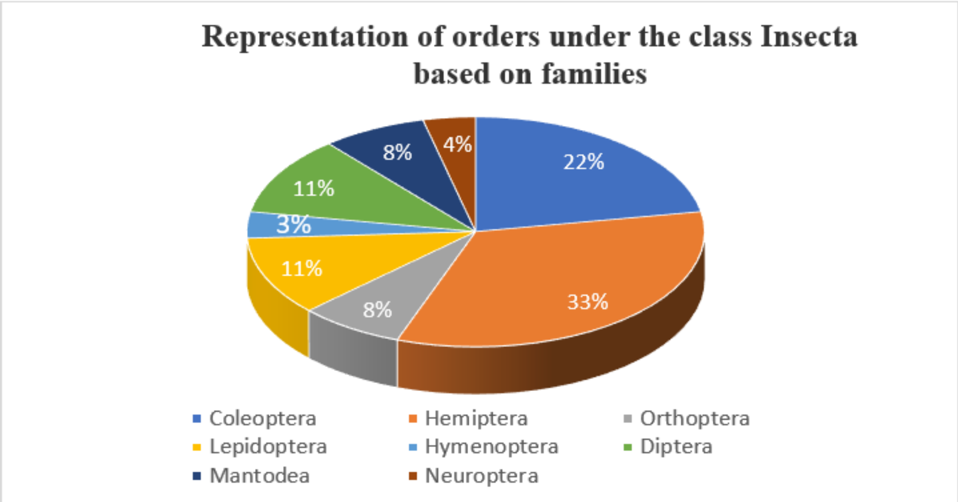
Plate 1 displayed the mulberry garden located within Holy Cross College, Nagercoil. Plate 2 and Table 1 documented and tabulated the arthropods identified on the stems, leaves, and stalks of the mulberry plants. In Arthropods, two classes, Insecta and Arachnida, were recorded. Within the class Insecta, eight orders were identified: Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, Orthoptera, Diptera, Mantodea, and Neuroptera.

Under the order Coleoptera, six families were observed: Scarabaeidae, Coccinellidae, Cerambycidae, Staphylinidae, Chrysomelidae, and Curculionidae. The genus *Heteronychus* was the sole representative of the Scarabaeidae family. In the

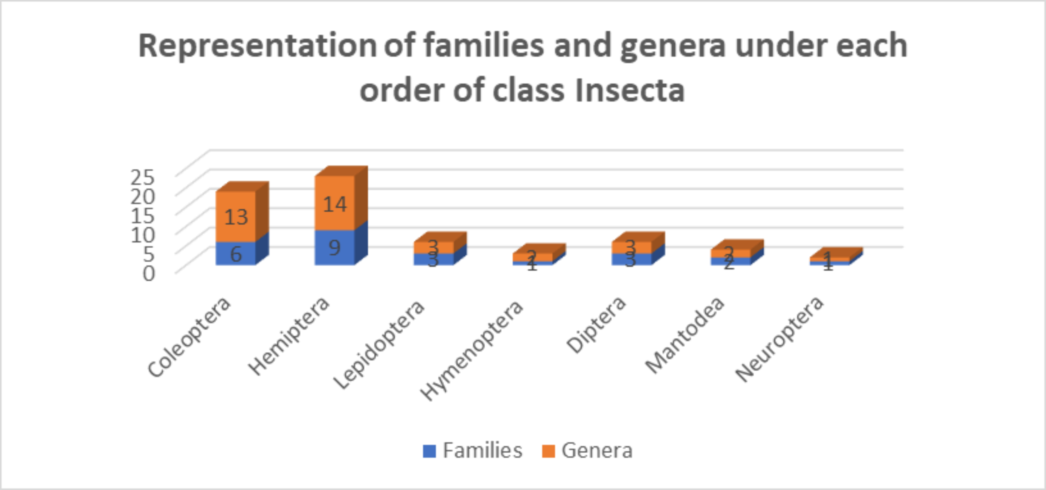
Coccinellidae family, four genera were recorded: *Cycloneda*, *Cheilomenes*, *Anegleis, and Harmonia*. Three genera were observed in the Cerambycidae family: *Eburia, Monochamus, and Sthenias*. The Chrysomelidae family contained two genera: *Phyllotreta* and *Altica*. The Curculionidae family included two genera: *Artipus* and *Otiorhynchus*, while the Staphylinidae family had one genus: *Paederus*. Within the order Hemiptera, nine families were identified: Pentatomidae, Coreidae, Flatidae, Membracidae, Jassidae, Reduviidae, Alydidae, Pseudococcidea, and Lygaeidae. The single genus was noted in some of these families, such as Oxyrachis, Amrasca, Rhynocoris, Leptocorisa, and Graptostethus, each belonging to distinct families. In the Pentatomidae family, two genera were recorded: Halynomorpha and Eysarcoris, while the Coreidae family contained two genera: *Anasa* and *Leptoglossus.* Additionally, the Pseudococcidea family featured three genera*: Pseudococcus*, *Planococcus*, and *Phenacoccus.*

The order Orthoptera included two families: Pyrgomorphidae and Lygaeidae. The Pyrgomorphidae family had the genus *Neorthacris*, and the Lygaeidae family included the genus *Graptostethus*. Three families, Nymphalidae, Erebidae, and Pieridae, were documented within the order Lepidoptera. Each of these families had one genus: *Heliconius*, *Orvasca*, and *Catopsilia*, respectively. The order Hymenoptera was represented by the family Formicidae, which contained two genera: *Gamponotus* and *Oecophylla*.

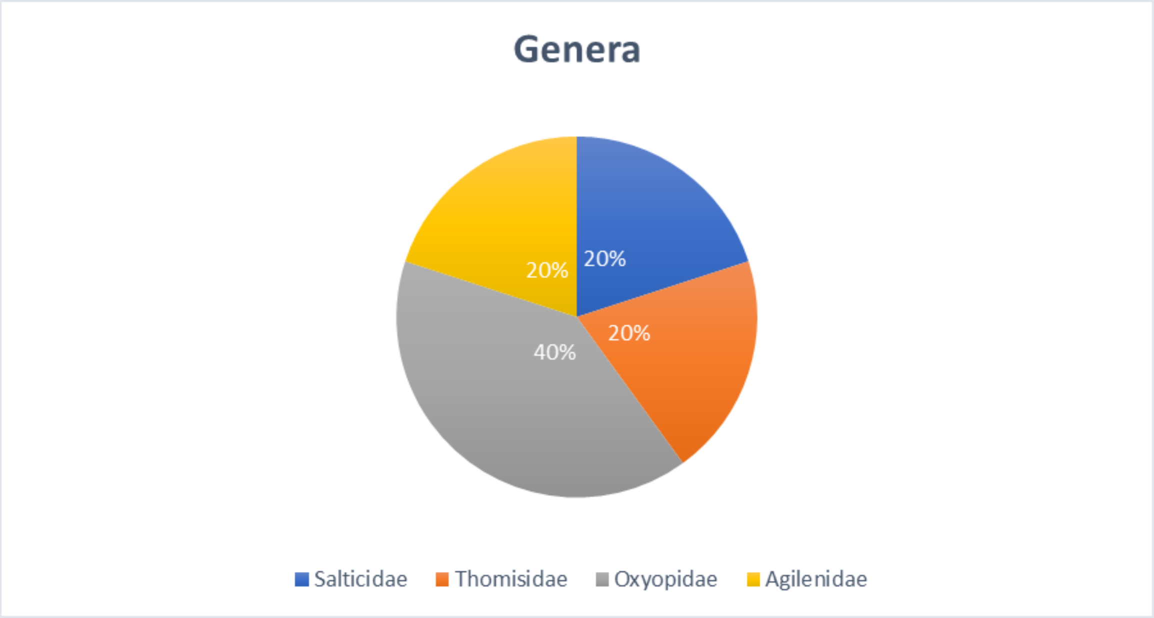
Within the order Diptera, three families were identified: Simuliidae, Dolichopodidae, and Stratiomyidae. These families were associated with the genera *Simulium*, *Austrosciapus*, and *Hermetia*, respectively. The order Mantodea included the families Mantidea and Hymenopodidae, with one genus each: *Mantis* and *Hymenopus*, respectively. In the order Neuroptera, the family Chrysopidae was observed, with one genus, *Apertochrysa*. In the class Arachnida, the order Araneae was the sole representation, with four families: Salticidae, Thomisidae, Oxyopidae, and Agelenidae. These families featured the genera *Carrhotus, Thomisus, Eratigena, Peucetia*, and *Telomonia.*



Graph 1 Representation of orders under the class Insecta based on families.



Graph 2 Representation of families and genera under each order of class Insecta.



Graph 3 Representation of families under the order Aranea of class Arachnida

Graphs 1, 2, and 3 illustrate the diversity of orders, families, and genera within the classes Insecta and Arachnida. Within the Insecta class, the Hemiptera order stands out with the highest count of families and genera, while the orders Hymenoptera and Neuroptera exhibit the lowest counts of families and genera. In contrast, within the Arachnida class, only the order Araneae is represented, and it shows a total of three genera. Table 2 indicates the Biodiversity indices of Arthropods.

Table 2: Biodiversity indices of Arthropods

Common name	P	Pi	Ln(Pi)	PiLn(Pi)	- PiLn(Pi)	Shannon – Weinner index	Species evenness	Species richness
Heteronychus	22	0.017	-4.075	-0.069	0.069	3.26	0.96	14.47
Cycloneda	34	0.027	-3.612	-0.098	0.098			
Cheilomenes	43	0.034	-3.381	-0.115	0.115			
Anegleis	32	0.025	-3.689	-0.092	0.092			
Harmonia	31	0.024	-3.730	-0.090	0.090			
Eburia	12	0.009	-4.711	-0.042	0.042			
Monochamus	16	0.013	-4.343	-0.056	0.056			
Sthenias	4	0.003	-5.809	-0.017	0.017			
Paederus	7	0.005	-5.298	-0.026	0.026			
Phyllotreta	4	0.003	-5.809	-0.017	0.017			
Altica	2	0.002	-6.215	-0.012	0.012			
Artipus	2	0.002	-6.215	-0.012	0.012			
Otiorhynchus	5	0.004	-5.521	-0.022	0.022			
Halynomorpha	31	0.024	-3.729	-0.089	0.089			
Eysarcoris	12	0.009	-4.711	-0.042	0.042			
Anasa	38	0.030	-3.507	-0.105	0.105			
Leptoglossus	3	0.002	-6.215	-0.012	0.012			
Phromnia	3	0.002	-6.215	-0.012	0.012			
Oxyrachis	4	0.003	-5.809	-0.017	0.017			
Amrasca	1	0.001	-6.908	-0.007	0.007			
Rhynocoris	20	0.016	-4.135	-0.066	0.066			
Leptocorisa	17	0.013	-4.343	-0.056	0.056			
Pseudococcus	247	0.193	-3.948	-0.762	0.762			
Planococcus	35	0.027	-3.612	-0.098	0.098			
Phenacoccus	26	0.020	-3.912	-0.078	0.078			
Graptostethus	11	0.008	-4.828	-0.039	0.039			
Neorthacris	14	0.011	-4.510	-0.050	0.050			
Bradynotes	17	0.013	-4.343	-0.056	0.056			
Melanoplus	13	0.010	-4.605	-0.046	0.046			
Schistocerca	14	0.011	-4.510	-0.050	0.050			
Heliconius	2	0.002	-6.215	-0.012	0.012			
Orvasca	4	0.003	-5.809	-0.017	0.017			
Catopsilia	1	0.001	-6.908	-0.007	0.007			
Gamponotus	67	0.052	-2.957	-0.154	0.154			
Oecophylla	342	0.268	-1.317	-0.353	0.353			
Simulium	6	0.005	-5.230	-0.026	0.026			
Austrosciapus	20	0.016	-4.135	-0.066	0.066			
Hermetia	3	0.002	-6.215	-0.012	0.012			
Mantis	7	0.006	-5.116	-0.031	0.031			
Hymenopus	1	0.001	-6.908	-0.007	0.007			
Apertochrysa	28	0.022	-3.817	-0.084	0.084			
Carrhotus	2	0.002	-6.215	-0.012	0.012			
Thomisus	3	0.002	-6.215	-0.012	0.012			
Peucetia	42	0.033	-3.411	-0.113	0.113			
Telamonia	22	0.017	-4.075	-0.070	0.070			
Eratigena	8	0.006	-5.116	-0.031	0.031			

DISCUSSION

The current investigation focused on identifying and analyzing the arthropods responsible for damaging mulberry leaves, with a particular emphasis on graphical representation. Two arthropod classes, Insecta and Arachnida, were observed, and the various families and genera within both classes were tabulated and graphically presented. Notably, Class Insecta exhibited a higher number of families compared to Arachnida. Within Insecta, the Hemiptera order stood out with a greater number of families and genera than other orders.

Interestingly, some previous research studies yielded similar findings, while others reported variations. For instance, Fatima *et al.*, 2018 identified several insect orders, including the Lepidoptera, Hemiptera, Coleoptera, Thysanoptera, Orthoptera, and Isoptera, as the primary culprits responsible for significant mulberry crop damage. They also recorded sap-sucking insects such as mealy bugs, thrips, spiraling whiteflies, hoppers, jassids, and aphids. In the present study, mealy bugs, hoppers, and jassids were also documented as contributors to the damage observed in mulberry leaves.

In the study conducted by Ugwu and Ojo in 2015, they identified a total of 24 insect species across nine insect orders, which included Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Diptera, Lepidoptera, Araneae, Mantodea, and Thysanoptera. Interestingly, the present study also recorded all of the above-mentioned orders, except for Thysanoptera.

In another study by Govindaiah *et al*., 2005, they reported the incidence of several insect pests, including mealy bugs (19.21%), thrips (17.18%), whitefly (12.62%), jassids (9.08%), and scale insects (8.24%). Vanitha *et al.*, 2019 conducted research and documented 27 species of insect fauna from 17 families across six orders, as well as 14 species of spiders from seven families under the order Araneae in bush mulberry. Their analysis using Shannon-Weiner diversity indices (H) indicated that the order Lepidoptera exhibited the highest diversity, followed by Araneae, Coleoptera, Hemiptera, Hymenoptera, Diptera, and Orthoptera. However, it's noteworthy that in the present study, Hemiptera demonstrated the highest species diversity. Additionally, the order Araneae was represented by only three species in the present study.

According to Mahadeva, 2018, important pests affecting mulberry foliage included leaf sap-suckers such as Jassids, Mealybugs, Thrips, and Spiralling whiteflies, as well as leaf rollers and leaf eaters like the Wingless grasshopper. The present study also confirmed the presence of Jassids, Mealybugs, and Wingless grasshoppers. Similar results were reported by Lalitha *et al.*, 2018. Reports from Raj *et al*., 2021 indicated the presence of nine spider families in mulberry plantations in Kanchipuram District. The dominant families observed in their study were Salticidae and Araneidae, with Salticidae being consistent with the findings of the present study.

The studies conducted by Obra, 2022 support the current research. He found that the most abundant insects in all collecting seasons belonged to the insect order Lepidoptera (larvae), accounting for 38% of the population. Other significant groups included Collembola (14%), Hymenoptera (11%), Hemiptera (9%), and 8% for other arthropods. Furthermore, Obra's research noted the presence of beneficial insects like some Coleoptera, Hymenoptera, Odonata, Orthoptera, and other arthropods, which served as natural enemies to insect pests. Some of these insects were considered pests themselves and were identified as defoliators (Lepidopteran larvae), sap suckers (Hemiptera and Homoptera), borers (Coleoptera), and pests inhabiting the soil (Isoptera).

The studies conducted by Noyes and Hayat, 1994 found that the order Hemiptera was the most prominent in the garden, making up approximately 60 to 62 percent of the insect population. Within the Hemiptera order, they recorded six homopterans and two heteropterans. The family Pseudococcidae, with four species of mealy bugs, was the largest family observed. Hymenoptera was the second most dominant order in the garden, and ants were found in association with the homopterans. Interestingly, there was a beneficial interaction observed between the homopterans and ants.

The order Coleoptera was the third largest in the garden, with coccinellids being the dominant group present year-round, a finding also reported by Joshi *et al*., 2004. Carabids were found alongside coccinellids in the field, and Allen, 1979 noted carabids as beneficial insects.

The mulberry ecosystem also contained insects from the orders Isoptera, Lepidoptera, Dictyoptera, Odonata, Orthoptera, and Thysanoptera. Among these orders, Odontotermes obesus of Isoptera, *Diaphania pulverulentalis* of Lepidoptera, and *Pseudodentrothrips mori* of Thysanoptera were identified as serious pests of mulberry, as reported by Prasad, S. *et al*., 2000 and Dandin *et al*., 2001.

The Shannon Weinner index, species evenness and species richness for the arthropods were observed to be on the greater side with a value of 3.26, 0.96 and 14.47 respectively. Similar results were recorded by Ferrenberg *et al*., 2006 in mixed coniferous forests. According to them, at the individual trapping point level, the late-season burn treatment exhibited higher species richness compared to the early-season burn treatment and the control group ($F_{2,6}=10.00$, $P<0.001$). When assessing arthropod community diversity using the Shannon index, both burn treatments showed greater diversity compared to the control group ($F_{2,6}=14.03$, $P<0.001$). The diversity index calculated by Tarihoran *et al.*, 2020 in sorghum plant also aligns with our result. According to them, the insect diversity index, registering at 3.115 (high), reflects a varied insect population thriving in a favourable habitat. A high evenness index (0.891) indicates a well-balanced distribution, while a richness index of 4.15 confirms a thriving ecosystem. These findings align with the research of various scientists and support the results of the present study. Additionally, studies conducted by Shanthi and Kumar, 2010 on the diversity of insects in the mulberry ecosystem in Nagercoil over two years also coincide with the findings of the current research.

CONCLUSION

In conclusion, the investigation into arthropods damaging mulberry leaves revealed a diverse array of insect and arachnid species responsible for crop damage. Notably, the order Hemiptera within Class Insecta was a prominent contributor to this damage, along with other insect orders such as Lepidoptera, Coleoptera, and Hymenoptera. While previous studies reported variations in the specific arthropod orders and families involved in mulberry damage, the present research consistently identified the presence of sap-sucking insects like mealy bugs, thrips, and jassids, along with leaf rollers and leaf eaters. These findings align with previous research in the field, emphasizing the ecological complexity of arthropods in mulberry ecosystems.

This research contributes to our understanding of the diverse arthropod community in mulberry cultivation and highlights the potential for different management strategies to mitigate crop damage while promoting biodiversity. This study strongly advocates the implementation of comprehensive and integrated management strategies to effectively combat the arthropod menace in mulberry gardens.

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