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Distribution, diversity and roles of insects in mulberry plantation

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Abstract

This study investigated the distribution, diversity and roles of insects in mulberry (*Morus alba* var. Alfonso) plantation that utilized survey and insect collection in January and September of 2019, reflecting the cool-dry and wet seasons respectively and the Shannon-Weiner diversity index (H) was employed to measure insect diversity and evenness. The abundant insects in all collecting seasons belong to insect order Lepidoptera (larvae) that accounted for 38%, Collembola (14%), Hymenoptera (11%), Hrmiptera (9%), and 8% for other arthropods while the insect diversity and evenness (H), were 2.28 and 0.82 for cool-dry season; and 1.954 and 0.762 for rainy season while t-test results exemplified similar insect diversity and evenness on both collecting seasons though some insects were abundant during rainy days. There were beneficial insects like some Coleoptera, Hymenoptera, Odonata, Orthoptera and other arthropods as natural enemies to insect pest; some were considered as pests and identified as defoliators (Lepidopteran larvae), sap suckers (Hemiptera and Homoptera), borers (Coleoptera) and some were pests inhabiting the soil (Isoptera). Collembolans were abundant in the soil as well which aid in the decomposition of organic matter forming soil microstructure and the recycling of nutrients to be used by mulberry plants for growth and development. Physical control measures such as individually picking the insects and removing the damaged parts of the mulberry are recommended to prevent further damage on mulberry plants. Intensified planning of mulberry pruning for silkworm rearing shall be considered so as not to coincide with excessive population of detrimental insects.

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Introduction

Mulberry plant of family Moraceae is a tough perennial and ephemeral tree, indigenous to China (Lalitha *et al*., 2018), however, the "silk trade" during the Han dynasty had helped its distribution to other parts of the world especially the tropics for silkworm production. The varieties of mulberry plants include *Morus nigra, Morus indica, Morus bombycis* and *Morus alba* L., var. Alfonso that thrives under the Philippine conditions particularly at the Sericulture Research and Development Institute (SRDI), Bacnotan, La Union, Philippines.

Mulberry plants are indispensable component of sericulture, the art and science of producing silk. Mulberry leaves are the only source of food for silkworms which form the cocoon for silk production. It is extremely considered that combinations of cultural practices shall aim in high yielding and quality leaves to generate superior silk cocoons. Mulberry plants provide ecological niche for insects and other arthropods satisfying their needs for growth and reproduction, (Santhi & Kumar, 2010). There are several insects, thriving in the mulberry ecosystem both beneficial and harmful to the plants. Insect pests that include Coleoptera, Lepidoptera, Hemiptera, Thysanoptera can cause damage to mulberry plant, often hampering the yield of appreciable quantity and quality mulberry leaves.

Santhi and Kumar (2010) mentioned that numerous insects have been recognized to bring about most damage to mulberry plants which consist of suck-sappers and thrips can cause severe curling and crinkling of leaves; and swelling and twisting of apical parts of the plant. In addition, aside from these insect pests, mulberry plantations are not spared from pathogens (fungi, bacteria, virus) and nematodes causing diseases to the plants like leaf spot, powdery mildew, leaf rust, and root diseases like root rot and root knot.

The beneficial species, such as predators that check the outbreak of insect pests in any agro ecosystem is being frequently disturbed. To understand the changes that impact the insect population imbalance, studies on species diversity of the affected agro ecosystem become indispensable.

This study determined the distribution, insect diversity and species richness utilizing Shannon-Weiner index, compared insect diversity between collecting seasons and identified the roles of the collected insects and other arthropods in mulberry plantation.

Materials and methods

Locale and Period of the Study

This study was conducted in January and September 2019 at the mulberry plantation along the Sericulture Research and Development Institute of the Don Mariano Marcos Memorial State University, Bacnotan, La Union, Philippines. The study site was located between N16°43.664' latitude, and E120°23.166' longitude with an elevation of 79.248 metres above sea level. The collections of insects were done in 2019 in the months of January representing the cool-dry season with an average temperature varying between 24.5°C and 30°C and with relative humidity of 81% and September representing the cool rainy season with an average temperature of 25.5°C and relative humidity of 72%. Mulberry trees had been pruned two months prior to the time of the study and collection time was done between 7 a.m. and 8 a.m.

The site has a land area of 1,160m² with 1,087 mulberry plants (Alfonso var.) approximately 1.5m high, and separated by one (1) meter between rows and 0.5m between hills.

Insect sampling

Insects were collected from the top of mulberry plants through net sweeping (Gibb and Oseto, 2019). The collected insects were put in an insect killing jar and later on preserved (A. Ghani and S. Maalik, 2020). In addition, leaves, shoots, trunks and twigs of the mulberry plants were closely observed for insects, which were then hand-picked. Berlese funnel traps (Raj, 2016) were left for 2 consecutive days to collect small insects from soil and leaf litter of the plantation. The soil-borne insects (and other arthropods) were initially identified and then counted under the dissecting microscope. All the insects collected were tallied, and were classified taxonomically up to the family level.

Analysis of Data

The collected insects were subjected to descriptive statistics and the and the Shannon-Weiner diversity index (*H*) was utilized to mathematically expressed both the abundance and evenness of the insects present in the mulberry plantation in the given period or season.

Results and discussion

Distribution of entomo-fauna

Table 1 presents the distribution of insect orders during the 2 collecting seasons. In season 1, Collembola, Lepidopteran larvae, Hymenopteran and Isoptera have high representatives with populations of 37, 35, 23, and 17 respectively while in the 2nd season, the order Lepidoptera (larvae) is the most dominant and largest insect order collected (107), followed by other arthropods (20), Hymenoptera and Hemiptera, both have 18 collected insect representatives.

The distribution of insect orders for both collecting seasons is illustrated in Fig. 1. It is shown that in both seasons, Lepidopteran larvae (39%) has the highest number followed by Collembola (14%) and Hymenoptera (11%). The insect order with the least number of representatives is Blattodea.

Table 1. Abundance of Insect Orders During the Two (Collecting Seasons.

Insect Order	January	September	Total Species
Lepidoptera (larvae)	35	107	142
Collembola	37	16	53
Hymenoptera	23	18	41
Hemiptera	15	18	33
Coleoptera	8	10	18
Isoptera	17	0	17
Orthoptera	0	16	16
Odonata	2	6	8
Homoptera	6	0	6
Diptera	2	0	2
Blattodea	1	0	1
Other Arthropods	9	20	29
TOTAL	155	211	366

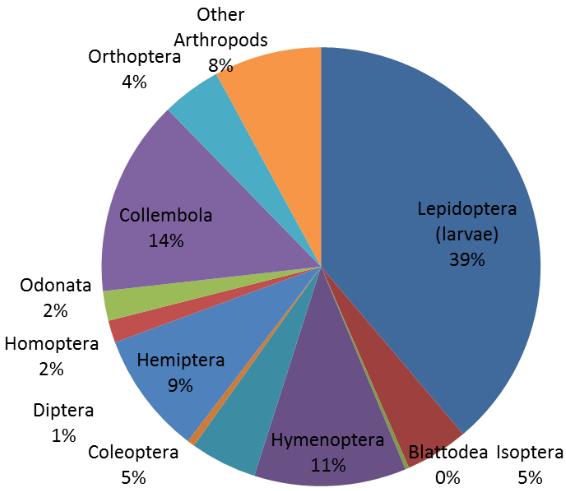

Fig. 1. Distribution of insect orders for both collecting seasons.

The abundant insect orders for both collecting seasons include the Lepidopteran larvae followed by Collembola and Hymenoptera while the Blattodea has the least number of insect order. Since the collection of insects was done a month after the mulberries were pruned and when healthy leaves developed, larvae became abundant to consume the leaves, this is also with the concept that the mulberry trees become an alternate hosts of insects since other crops planted near the mulberry plantation had been harvested.

The findings corroborates with that of Ugwu and Ojo (2015) and that of Santhi and Kumar (2010) signifying that there is abundance of insects thriving in mulberry plantation. Lepidopterans constituted the most abundant insect order assessed, similar to the study of Seong-Joon Park (2014) on the survey of insect diversity of Baengnyeongdo, Korea, however, in the studies of Ugwu and Ojo (2015), Santhi and Kumar (2010) had Hymenoptera and Hemiptera respectively as the most abundant insect orders. In both collecting seasons, it is further revealed in this study that the abundant insect orders are Lepidoptera and Collembola.

Insect diversity measurements using Shannon-Weiner Index

Table 2 denotes the insect and other arthropod diversity in the mulberry plantation through Shannon-Weiner index and evenness during the cool dry season (Season 1). During this season, there are 16 species collected with 155 individual insects. It can also be noted that the computed Shannon-Weiner index is 2.28 and an evenness of 0.82, signifying a highly diverse mulberry ecosystem.

The diversity index results obtained by Ugwu and Ojo (2015) using the Simpson's index were descriptively similar as well to the results obtained from this investigation which used the Shannon-Weiner Diversity index. It implies that mulberry plantation is a diverse ecosystem holding several numbers and various species of insects and other arthropods.

Table 3 presents the insect and other arthropod diversity in the mulberry plantation through Shannon-Weiner index and evenness during the rainy season (Season 2). It could be gleaned from the table that the diversity utilizing the Shannon-Weiner Diversity index is 1.954 and an evenness of 0.762 by which these results express high species diversity or abundance of different species in the mulberry plantation.

Table 2. Shannon-Weiner Diversity Index and Evenness of Insects and Other Arthropods in Mulberry (*Morus alba*, Alfonso var.) Plantation During Season 1 (cool-dry).

Order	Family Name	Ni	Pi	lnPi	-(Pi*lnPi)	LnS	Evenness
Lepidoptera	Pyralidae (larvae)	35	0.226	-1.488	-0.336	2.773	0.820
Isoptera	Termitidae (workers)	17	0.110	-2.210	-0.242		
Blattodea	Blattidae (cockroach)	1	0.006	-5.043	-0.033		
Hymenoptera	Formicidae (red ants)	23	0.148	-1.908	-0.283		
Coleoptera	Coccinilidae (Lady bug)	5	0.032	-3.434	-0.111		
	Salpingidae (Narrow-waisted bark beetle)	1	0.006	-5.043	-0.033		
	Dermestidae (Beetle)	2	0.013	-4.350	-0.056		
Diptera	Calliphoridae (blowfly/mettalic flies)	2	0.013	-4.350	-0.056		
Hemiptera	Ricaniidae (Plant hopper)	3	0.019	-3.945	-0.076		
	Pseudococcidae (mealy bug)	12	0.077	-2.559	-0.198		
Homoptera	Cicadellidae (Leafhoppers)	6	0.039	-3.252	-0.126		
Odonata	Aesnidae (Common dragonfly)	2	0.013	-4.350	-0.056		
Collembola	Isotomidae	29	0.187	-1.676	-0.314		
	Entomobryidae	8	0.052	-2.964	-0.153		
Other Arthropods							
	Tertranychuss spp (Red spider mites)	6	0.039	-3.252	-0.126		
	Arachnid (spiders)	3	0.019	-3.945	-0.076		
	Total no. of species	16					
	Total no. of individuals	155		H=	2.28		

Table 3. Shannon-Weiner Diversity Index and Evenness of Insects and Other Arthropods in Mulberry (*Morus alba*, Alfonso var.) Plantation During Season 2 (rainy).

Insect Order	Family	Ni	Pi	lnPi	-(Pi*lnPi)	lnS	Evenness
Lepidoptera	Pyralidae (larvae)	107	0.633	-0.457	-0.289	2.565	0.762
Hymenoptera	Formicidae (red ants)	18	0.107	-2.240	-0.239		
Coleoptera	Coccinilidae (Lady bug)	8	0.047	-3.050	-0.144		
	Cerambycidae (Longhorn beetle)	2	0.012	-4.437	-0.053		
Orthoptera	Acrididae (Grasshopper)	10	0.059	-2.827	-0.167		
	Tettigoniidae (Bush cricket)	5	0.030	-3.520	-0.104		
	Gryllotalpidae (Mole Cricket)	1	0.006	-5.130	-0.030		
Hemiptera	Ricaniidae (Plant hopper)	18	0.107	-2.240	-0.239		
Odonata	Aesnidae (Common dragonfly)	6	0.036	-3.338	-0.119		
Collembola	Isotomidae	14	0.083	-2.491	-0.206		
	Entomobryidae	2	0.012	-4.437	-0.053		
Other Arthropods							
	Tertranychuss spp (Red spider mites)	16	0.095	-2.357	-0.223		
	Arachnid (spiders)	4	0.024	-3.744	-0.089		
	Total no. of species	13					
	Total no. of individuals	169		H=	1.954		

During the rainy season (Season 2), a diverse mulberry ecosystem is also observed, this substantiates with the investigations of Ugwu and Ojo (2015) that there were also different representatives of insect orders during the rainy season, however, refutes their findings on the highest insect density recorded during the same season, specifically the month of June. It is revealed in this study that it was during the cool-dry season (September) that exemplified the highest insect diversity recorded.

Ugwu and Ojo (2015) also found out that it was during the rainy season that damaging insect species was relatively high. Their findings had been supported in this exploration because of the abundance of Lepidopteran larvae surveyed destroying leaves on the apical shoots of the mulberry plants.

Insect diversity and seasons

Table 4 shows the computed T-test results, one tail and two tail of Shannon-Weiner diversity index of insects and the particular seasons (cool-dry and rainy), the insects were surveyed. It further shows that the P values (one tail and two tail) are greater than 0.05, which signify that there are no statistical significant differences on the insect diversity index and the seasons by which the insects were surveyed. It could be deduced from the aforementioned results that in the mulberry plantation of similar age and form, the type of season, whether cool-dry and rainy, the abundance and diversity of insects or arthropods are similar.

Table 4. T-test Results of the Insect Diversity Index and Seasons.

	Season 1 (Cool-dry)		Season 2 (rainy)	
Mean	9.688	16.231	0.063	0.096
Variance	114.629	781.192	0.005	0.027
Observations	16	13	16	13
Pooled Variance	410.879		0.015	
Hypothesized Mean Difference	0		0	
df	27.000		27.000	
t Stat	-0.865		-0.738	
P(T<=t) one-tail	0.197	ns	0.233	ns
t Critical one-tail	1.703		1.703	
P(T<=t) two-tail	0.395	ns	0.467	ns
t Critical two-tail	2.052		2.052	

ns: Not significant; P value is greater than 0.05

Moreover, results strengthen the findings of Ugwu and Ojo (2015) that generally, insect fauna as a whole showed no seasonal variation in abundance, however, some individual insect orders showed significant seasonal variation like in the case of Lepidopteran larvae which were abundant during the rainy season.

Siddiki (2015) reiterated in his study, however, that diversity and abundance of insects were higher during the wet season as compared to the dry season.

The contradicting attribute was on the type of agro ecosystem by which the insects were surveyed. This study and that of Ugwu and Ojo (2015) ventured on mulberry plantations while that of Siddiki (2015) explored on forest ecosystem comprised of various vegetation.

Insects and Non Insects as Pests and their Ecological Roles

Table 5 illustrates the classifications of the collected insects. As presented by Sakthivel, *et al.* (2019), the classifications or categories of insects as to the nature of damage they pose to their hosts, are defoliators, sap-suckers, borers, soil-dwelling pests, soil builders/decomposers, non-insect (other arthropods) pests, and natural enemies.

Table 5. Classification of the Insects for Both Collecting Seasons.

Classification	Collected insects and other arthropods		Frequency
	Order	Family	
Defoliators	Lepidopteran larvae	Pyralidae	142
Sap-suckers	Hemiptera	Ricaniidae	21
		Pseudococcidae	12
	Homoptera	Cicadellidae	6
Borers	Coleoptera	Salpingidae	1
		Cerambycidae	2
Soil-dwelling pests	Isoptera	Termitidae	17
Soil-builders/ Decomposers	Coleoptera	Dermestidae	2
	Collembola	Isotomidae	43
		Entomobryidae	10
Generalist arthropod predators/Natural enemies	Blattodea	Blattidae	1
	Coleoptera	Cocciniidae	13
	Diptera	Calliphoridae	2
	Hymenoptera	Formicidae	43
	Odonata	Aesnidae	10
	Orthoptera	Acrididae	10
		Tettigoniidae	5
		Gryllotalpidae	1
Non insect natural enemies	Other arthropods	Arachnids	7
Non-insect pests	Mites	Tertranychuss spp	22

It could be deduced from the table that the defoliators, Lepidopteran larvae, Pyralidae constitute the most number (142) of insects in the mulberry plantation during the two collection seasons followed by Collembolans, Isotomidae (43), and general arthropod predator/natural enemies, Hymenopterans -Formicidae (41) and the least are the borers, under insect Order Coleoptera; and Families, Salpingidae (1) and Cerambycidae (2).

Defoliators are insects that cause tree damage by feeding on the leaves or needles. In most cases, the insect larvae—not the adults—do the damage. These include the Lepidopteran larvae (Pyralidae).

Sap-suckers are insects equipped with penetrating mouthparts, allowing them to feed on tree sap causing harm to trees by piercing the surface of soft plant tissues and feeding on nutrient-rich sap. In sufficient numbers, piercing/sucking insects can starve a tree by depleting it of the carbohydrates produced from photosynthesis. If infestations last several years, tree death can result. The sap sucker insects surveyed include the mealy bug (Hemiptera.- Pseudococcidae), leaf hopper (Homoptera-Cicadellidae), and plant hopper (Hemiptera-Ricaniidae).

Borers are insects that attack trees by tunneling underneath the bark. The soft cambium and newly produced wood and bark cells are destroyed. This effectively girdles the tree, cutting off the supply of nutrients. In addition, the damage often provides an entry point for diseases and other pests to attack the tree. The insect borer surveyed was the longhorn beetle (Coleoptera-Cerambycidae).

Termites (Isoptera-Termitidae) are soil inhabiting pests which feed on the bark and hard wood. Hence, cuttings dry up and no sprouting takes place. In old plantations, they first infest the dry twigs. Later they slowly move to live twigs.

Non-insect pests include the Red spider mites (Arachnida-Trombidiformes-Tetranychidae) feed on the leaves through their piercing-sucking mouthparts. They remove contents from individual plant cells, leaving behind the cell wall, which makes the emptied cells appear silvery. The most noticeable damage of symptom of infestation is white stippling on the leaves. Heavily infested plants take on a faded, yellowish or greyish cast.

Generalist arthropod predators act as natural enemies of agricultural pests capturing and devouring harmful insects. They are considered natural enemies feeding on other predators consuming plant parts, thus, providing natural control. The natural enemies include some species of Coleoptera (lady bugs/beetles), and Arachnids (spiders) which were identified by Ayan Das, *et al.* (2021) and Hemipteran which feed on aphids, moth eggs, small caterpillars, scale insects, spider mites, white flies, etc.

Soil builders such as ants, beetles, larvae of cutworms and collembola make tunnels in the soil and facilitate aeration in the soil. Springtails or collembollans are found abundantly in many types of moist situations, including deep leaf mold, damp soil, rotten wood, the edges of ponds or streams, and fleshy fungi. Many species of Collembolans eat nematodes and some species ingest even plant-pathogenic fungi (Coleman, 2013). In addition, Innocenti and Sabatini (2018) specified on their review that Collembolans have been found to feed preferably on pathogenic rather than on antagonistic or *arbuscular mycorrhizal* (AM) fungal propagules, like that of causing mulberry root rot, thus, springtails can reduce the inoculum of pathogens without counteracting the activity of fungi beneficial for plant growth and health.

The above results reinforce the findings of Sakthivel, *et al.* (2019) classifying the various insects in mulberry plantation such as suck suckers, defoliators, borers, soil- inhabiting pests and these are mainly the pests in mulberries.

In addition, the findings corroborate that with of Mahesha (2018) which classified the insects on mulberry plants as pests, namely, sap-suckers, defoliators, borers, soil- inhabiting pests, non-insect pests specifically the Red spider mite.

Conclusion

During the cool-dry and rainy seasons, the abundant insects belong to insect orders Collembola, Lepidoptera, Hymenoptera and Hemiptera and other arthropods. The abundance and variations of insect species had been determined utilizing the Shannon-Weiner Diversity index with H values (index), 2.28 with evenness of 0.82 and 1.954 with evenness of 0.762 in season 1 (cool-dry) and season 2 (rainy) respectively signifying a well-diverse insect species in the mulberry plantation. Some of the surveyed insects and other arthropods were considered pests and they caused damages to the mulberry plants and categorically classified as defoliators, sap-suckers, borers and some were pests inhabiting the soil. If there were pests that abound the mulberry plantation, there were also beneficial insects and other arthropods as natural enemies to these pests, like some Coleopterans and Orthoptera; Collembola regulates the microorganisms responsible for the decomposition of organic matter forming soil microstructure and the recycling of nutrients that will be used by plants, specifically the mulberries for their development.

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