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Arboreal arthropod assemblages in chili pepper with different mulches and pest managements in freshwater swamps of South Sumatra, Indonesia

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Abstract. *Herlinda S, Tricahyati T, Irsan C, Karenina T, Hasbi, Suparman, Lakitan B, Anggraini E, Arsi. 2021. Arboreal arthropod assemblages in chili pepper with different mulches and pest managements in freshwater swamps of South Sumatra, Indonesia. Biodiversitas 22: 3065-3074.* In the center of freshwater swamps in South Sumatra, three different chili cultivation practices are generally found, namely differences in mulch and pest management that can affect arthropod assemblages. The effect of mulches and pest management on arboreal arthropod assemblages specific to chili production centers in the freshwater swamps of South Sumatra has never been investigated. This study aimed to observe arboreal arthropod assemblages in chili with different mulches and pest management. Arboreal arthropods were sampled using sweep nets in three locations with plots treated with leaf litter mulch and bioinsecticide, plastic mulch and synthetic insecticide, and weedy plot without mulch with synthetic insecticide. The species number of arboreal arthropods found was 28 species of Arachnids and 23 species of Insects, and consisting of 6 families of the Arachnids and 25 families of Insects. The abundance of arboreal arthropods was 65.60 individuals/5 nets per observation. In the chili field without mulch but with the insecticide, the species biodiversity and abundance of arboreal predatory arthropods were the highest. In contrast, in the chili field, that applied with synthetic insecticides and plastic mulch, the abundance of arboreal predatory arthropods was the lowest. The herbivorous insect populations in chili with plastic mulch and synthetic insecticides and the chili with the leaf litter mulch were higher than those in the chili without mulch. In the chili with the leaf litter mulch and bioinsecticide, the species number and abundance of the spiders were the highest compared to the other chili fields. The weedy chili field without mulch and chili with the leaf litter mulch has proved ideal habitats for the arboreal predatory arthropods.

Keywords: Herbivorous insect, leaf litter mulch, plastic mulch, predatory arthropod, weedy chili field

INTRODUCTION

Freshwater swamps are wetlands inundated by water from rivers or rain (Hanif et al. 2020). The duration and depth of the inundated water determine the type of the freshwater swamp, namely shallowly flooded (depth <50 cm for 3 months), moderately flooded (50-100 cm depth for 3-6 months), and deeply flooded (depth> 100 cm for 6 months) swamps (Lakitan et al. 2019). The three typologies of swamps influence the tradition of farmers in cultivating agricultural commodities (Lakitan et al. 2018). In shallowly flooded swamps, the farmers generally plant adaptive vegetables and food crops, for example, chili pepper or chili, corn, eggplant, paddy, long beans, ridged gourd, bitter melon, or cucumber (Siaga et al. 2019; Karenina et al. 2020a). In the moderately flooded swamps, they generally grow rice, while chilies and other adaptive vegetables are grown on paddy embankments (Herlinda et al. 2019). In the deeply flooded swamp, we have found that the smallholder farmers traditionally raise the swamp buffalo (*Bubalus bubalis* (L.)) or the local duck, "*pegagan* duck" (*Anas platyrhynchos* L.), while entrepreneur farmers can still plant paddy using the pumping system or plant chilies using the "*surjan*" system (alternating bed system).

Chili (*Capsicum annuum* L.), a leafy vegetable with high economic value, is cultivated the most widely after or simultaneously with paddy in the freshwater swamps center in South Sumatra (Siaga et al. 2018). Cultivation of chilies is carried out by both the smallholders, middle, and the large-scale farmers (Lakitan et al. 2019) to form groupings, each of which has specificities in the management practices. The grouping consists of the subsistent farmers with low input production and farmers with medium capital and the large-scale farmers with medium to high production input. In general, the differences between these three chili cultivation practices are the differences in the use of mulch and the management of pests and diseases.

Different mulches and pest management in chili can affect arthropod assemblages. Plastic mulch can reduce the population of herbivorous insects in chilies and other vegetables (Kolota and Adamczewska-Sowinska 2013), for example, *Thrips parvispinus* (Karny) (Nasruddin et al. 2020) and *Thrips palmi* (Karny) population (Razzak et al. 2019; Nasruddin et al. 2020). The reflective silver mulch can reduce the population of nymphs and adults of whitefly (*Bemisia tabaci* (Gennadius)) in chilies (Agus et al. 2019). Cultivating environmentally friendly chilies without using fertilizers and synthetic insecticides on chilies can increase the presence of natural enemies of the chili leaf curl vector insect (Rondonuwu et al. 2014). In addition, the living mulch and no herbicide application can increase the abundance of the predatory arthropods due to the increasingly complex flora (weedy field) in the agroecosystem (Bryant et al. 2013). However, the plastic mulch can reduce the abundance of the predators (Razzak et al. 2019), but some researchers claim that the reflective plastic mulch does not affect the abundance of predatory arthropods (Nottingham et al. 2016). Intensive pest control using synthetic insecticides can reduce abundance and species diversity, for example, a decrease in the abundance and diversity of predatory arthropods after being applied with synthetic insecticides (Biondi et al. 2012; Hanif et al. 2020).

The effect of mulches and pest management on arboreal arthropod assemblages specific to chili production centers in the freshwater swamps of South Sumatra has never been investigated. This study provides new information on the influence of farmers' habits and location-specific chili managements in the chili production centers in freshwater swamps, South Sumatra against the arboreal arthropod assemblages (predators and parasitoids, neutral insects, and the herbivorous insects). Chili managements that promote the natural enemy arthropod community (predators and parasitoids) and neutral insects are useful for application in other ecosystems to maintain the stability of the chili ecosystem. This study aimed to observe arboreal arthropod assemblages in chili with different mulches and pest managements in freshwater swamps of South Sumatra, Indonesia.

MATERIALS AND METHODS

Study area

The survey was conducted from April to October 2019 in three villages, namely Indralaya (S 3°12'38.12" E 104°39'08.23"), Tanjung Seteko (S 3°12'44.02" E 104°41'05.83"), and Pulau Negara (S 3°11'20.07" E 104°41'00.21"), Ogan Ilir District, South Sumatra (Figure 1). The selection of survey locations was based on the differences in how local farmers cultivated chilies. The most basic differences were due to the differences in the use of mulch and pest management. The sample location with cultivation practices using leaf litter mulch with environmentally friendly controls, namely spraying bioinsecticides was selected in Indralaya Village (A). The sample location with the practice of cultivating chili using plastic mulch and controlling pests using synthetic insecticides was selected in Tanjung Seteko Village (B), while the location for chili without mulch (weedy plot without mulch) but spraying synthetic insecticides was selected in Pulau Negara Village (C). The area of each sample location was ~ 1 ha. These three types of locations were the examples of the habits most often practiced by the farmers in chili production centers in South Sumatra, however in location A it was slightly modified, usually, the farmers did not control pests but in this study, the bioinsecticide from entomopathogenic fungi was applied.

Survey location characteristics

The first location (A) was sprayed with a bioinsecticide containing the active ingredient *Beauveria bassiana* (Balsamo) Vuillemin at a dose of 2 L ha^{-1} which was made following the method of Prabawati et al. (2019). It was sprayed every two weeks from 14 days after planting until 140 days after planting. The litter mulch used in location A came from weeds and seasonal wild plants from the weeding waste at the chili location and its surroundings. At location A, the fertilizer used was only manure at a dose of 20 tons ha^{-1} (Table 1). Location A was generally carried out by smallholder farmers who lacked the capital to buy plastic mulch and synthetic pesticides. However, at location A there was a slight modification of the local farmers' habits, namely by adding bioinsecticide application. Although the local farmers have not widely adopted the use of this bioinsecticide in South Sumatra, we observed that several assisted farmers have started to try to apply this bioinsecticide and the easiest way they collected entomopathogen-attacked insects from their own location.

The second location (B) was a stretch of land using silver plastic mulch and spraying using synthetic pesticides with active ingredients, including propinep, profenofos, and Lambda-cyhalothrin, while the fertilization used synthetic fertilizers (16% nitrogen, 16% phosphate/P_2O_5, 16% Kalium/K_2O) according to the recommended dose and manure 20 tons ha^{-1}. Spraying at location B was carried out intensively and weekly starting 7 days from after planting until harvesting. Location B was generally conducted by the large-scale farmers having big capital.

The third location (C) was a stretch of land that did not use mulch. The location got weedy; spraying of synthetic pesticides with the active ingredient difenoconazole, and diafenthiuron. Spraying was only carried out at the beginning of the planting when the chilies were 14, 21, and 28 days after planting. The dominant weed species were *Chromolaena odorata* L., *Ageratum conyzoides* L., *Borreria latifolia* Aubl., *Trema orientalis* L., *Physalis angulata* L. The fertilization using synthetic fertilizers according to the recommended dosage and manure 20 tons ha^{-1}.

Arboreal arthropod sampling

Arboreal arthropod sampling was performed 14, 28, 42, 56, 70, 84, 98, 112, 126, and 140 days after the chili seedlings were planted (DAP) in each type of location.

Arboreal arthropods were sampled using sweep nets following the method of Herlinda et al. (2018). Each type of location was divided into three subplots which were replicates (pseudoreplication). Each subplot was sampled at five sampling points (5 plants) spreading out at each corner of the subplot and in the center of the subplot. The arthropod sampling was carried out in the morning from 06.00 a.m. to 08.00 a.m. The obtained arthropods were put into vials containing 96% ethanol, labeled with the location and date of sampling then taken to the Entomology Laboratory of the Department of Plant Pests and Diseases, Faculty of Agriculture, Universita Sriwijaya to be identified morphologically using books written by Heinrichs et al. (2017), and Whyte and Anderson (2017) and the number of individuals of each species from each survey location was recorded. The identification of arthropods was carried out by Dr. Chandra Irsan, an insect taxonomist of Universitas Sriwijaya.

Data analysis

The number of species and the number of individuals in each species (the abundance) from each location were used to analyze the abundance and species diversity. Shannon-Wiener index (H'), dominance (D), and Evenness (E) were calculated to Magurran (2004). The arthropods were grouped based on the guilds, namely the predatory arthropods (spiders and predatory insects), parasitoids, herbivorous insects, and neutral insects (pollinators and decomposers) following the method of Karenina et al. (2019), then the data were displayed in graphs or tables.

Table 1. Characteristic of three chili fields with different management practices in South Sumatra, Indonesia

Characteristic	A	B	C
Location (village)	Indralaya	Tanjung Seteko	Pulau Negara
Planting method	Planting seedlings	Transplanting	Transplanting
Water management	Manual watering	Pumping system	Pumping system
Planting period	May-August	May-August	May-August
Seed treatments	Bioinsecticide of *Beauveria bassiana*	Difenoconazole	Without seed treatments
Seeds	Hybrid seeds	Self-produced seeds	Self-produced seeds
Weed control/mulch	Leaf litter mulch	Plastic mulch	Without mulch/weedy
Pest control	Bioinsecticide of *Beauveria bassiana*	Propinep, Profenofos, λ-cyhalothrin	Difenokonazol, Diafentiuron
Fertilizers	Manure	Manure and synthetic fertilizer	Manure and synthetic fertilizer
Other crops around chili	Oil palm ~40 ha, and rubber ~ 10 ha	Chili and other vegetables ~ 30 ha, cucumber ± 1 ha, bitter melon ± 2 ha, and watermelon ~ 0.5 ha	Chili ~200 ha and rice ~ 300 ha

Note: A: plot with leaf litter mulch, B: plot with plastic mulch, C: weedy plot without mulch

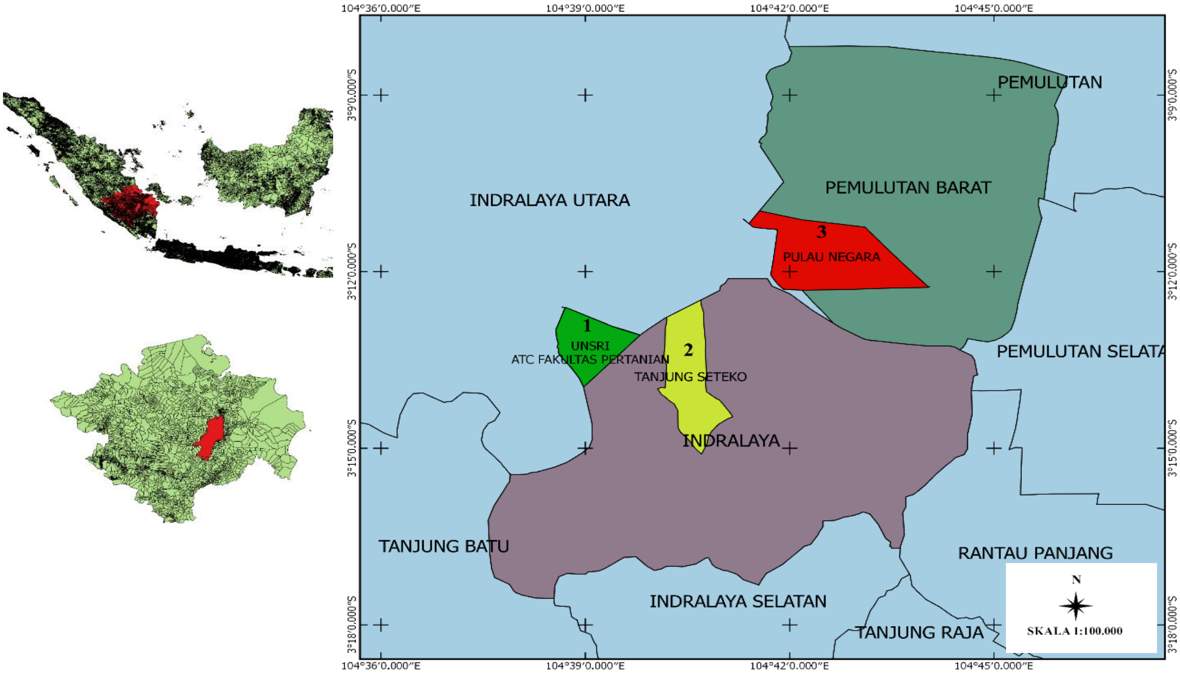


Figure 1. Locations of the survey in three chili fields: 1. Indralaya, 2. Tanjung Seteko, 3. Pulau Negara in the center of freshwater swamps of South Sumatra, Indonesia

RESULTS AND DISCUSSION

Specific identity and abundance of arboreal arthropods

The species number of arboreal arthropods found in chili production in South Sumatra was 51 species (Table 2). The found species belonged to the classes of Arachnida and Insecta. From the class of Arachnida, there were 6 families, while from the class of Insecta there were 25 families. The mean abundance of arboreal arthropods found location A (a plot with leaf litter mulch) as many as 23.60 individuals/5 nets (from one subplot), at location B (a plot with plastic mulch) as many as 20.07 individuals/5 nets, and at location C (a weedy plot without mulch) as many as 21.93 individuals/5 nets.

The dominant species of predatory arthropods (insects and spiders) were found in the three survey locations, including *Oxyopes macilentus* L. Koch, *Oxyopes variabilis* L.Koch, *Pardosa pseudoannulata* Boes. & Str., *Harmonia octomaculata* F., *Menochilus sexmaculatus* F, *Coelophora inaequalis* F, *Arisolemma dilatata* I, *Micraspis inops* Mulsant, *Paederus fuscipes* Curtis, and *Andrallus spinindens* F. (Figure 2). The number of species of predatory arthropods at location A was found as many as 17 species, at location B as many as 13 species, and the most species were found at location C (20 species). The number of species and abundance of spiders at location A was the highest compared to locations B and C. At location C there were found hunting spiders, *P. pseudoannulata* while at locations A and B the species was not found (Table 2). The most abundant arboreal predatory arthropods were found at location C (11.90 individuals/5 nets), while the least abundance was found at location B (3.60 individuals/5 nets). The most dominant species found in location A was *Harmonia* sp., at location B the most dominant species was *M. sexmaculatus*, while at location C the most dominant species found was *H. fasciatus*.

The dominant herbivorous insect species were found in the three survey locations, including *Aphis gosypii* Glover, *Aleurodicus dugesii* Cockerell, *Empoasca* sp., *Aulacophora dorsalis* Boisduval, and *Aulacophora indica* Gmelin (Figure 3). *A. gosypii, A. dugesii*, and *Empoasca* sp. were found in this study (Table 2) and the three herbivore species were the key pests in chilies. *A. gosypii* and *Empoasca* sp. found in either location A, B, or C. At location B that used plastic mulch, the two key pests were still found. *A. dugesii* was found only at location A. The high abundance of the herbivores was found at location A (16.87 individuals/5 nets) and at location B (15.57 individuals/5 nets), while the least abundance was found at location C (8.43 individuals/5 nets) (Table 2).

Apart from the predatory arthropods and herbivorous insects, this study found parasitoids and neutral insects. The species of parasitoids were found only 3 species, namely *Sceliphron* sp. (A), *Apanteles* sp. (B) and *Cotesia* sp., three species were successfully documented in the canopy of chilies (Figure 4). The highest parasitoid abundance was found at location A (0.43 individuals/5 nets), while the lowest abundance was found at location C (0.03 individuals/5 nets) (Table 2). There were 6 neutral insect species found, including *Chironomus* sp. and *Musca domestica* (Figure 5). The high abundance of the neutral insects was found at location A (1.80 individuals/5 nets) and location C (1.57 individuals/5 nets), while the least abundance was found at location B (0.80 individuals/5 nets). During one growing season, the number of arboreal arthropod species found in location C was the most (33 species), followed by location A (31 species), while the least was found in location B (27 species).

The arboreal arthropod assemblages

The highest number of species of the arboreal predatory arthropods (20 species) was found in location C compared to the number of species in locations A (17 species) and B (13 species) (Table 2). The index value of the species diversity at location C was also the highest (2.44) with the dominant species of only 0.24 of the predatory arthropods (Table 3). Location B, apart from having the highest species diversity, also had the highest abundance. The lowest species diversity index was found at location B and the abundance was also the lowest. The most abundant of predatory arthropods was from the family of Coccinellidae (Figure 6). At location C, the abundance of Syrphidae was also high, whereas at location B almost all the families had a low abundance.

The highest number of herbivorous insects (9 species) was found at location C, while in location A there were 8 species found (Table 2). Yet, the index value of the species diversity at location C was also the lowest (1.15) with the dominant species was the highest 0.69 (Table 3). The predominant species in the three locations was *A. gosypii*. Location C was the lowest abundance, while the abundance of these insects was high at locations A and B. The abundance of herbivorous insects originating from the family of Aphididae was the highest in all types of locations. At location B, the abundance of Chrysomelidae and Cicadellidae was also high, whereas in location C only the Aphididae family was dominant.

Based on the guilds, the arthropods found consisted of predatory arthropods, parasitoids, herbivorous and neutral insects. The proportion of the arboreal arthropods varied among guilds (Figure 7). In this study, the new information found was the dominance of the predatory arthropods at location C (54%), while the herbivorous insects only occupied 39% (Figure 7). The herbivorous insects dominated at locations A (71%) and B (78%). The highest proportion of neutral insects was found in locations A (8%) and C (7%), while the lowest one was in location B (4%).

Table 2. Species composition and abundance of arboreal arthropods found in three chili fields with different management practices

Class/Ordo/Families	Species	Guilds	A	B	C
			Mean abundance per subplot (Individual/5 nets)		
Insecta/Coleoptera/Carabidae	*Cicindela* sp.	PR	0.20	0.00	0.00
Insecta/Coleoptera/Coccinellidae	*Harmonia* sp.	PR	1.43	0.00	1.30
Insecta/Coleoptera/Coccinellidae	*Micraspis inops*	PR	0.50	0.00	0.93
Insecta/Coleoptera/Coccinellidae	*Menochilus sexmaculatus*	PR	1.07	1.03	0.70
Insecta/Coleoptera/Coccinellidae	*Arisolemma dilatata*	PR	0.00	0.70	0.00
Insecta/Coleoptera/Coccinellidae	*Harmonia octomaculata*	PR	0.10	0.30	0.00
Insecta/Coleoptera/Coccinellidae	*Micraspis discolor*	PR	0.13	0.00	0.13
Insecta/Coleoptera/Coccinellidae	*Scymnus coniferarum*	PR	0.00	0.00	0.07
Insecta/Coleoptera/Coccinellidae	*Coelophora inaequalis*	PR	0.10	0.00	0.40
Insecta/Coleoptera/Coccinellidae	*Micraspis* sp.	PR	0.00	0.00	0.57
Insecta/Coleoptera/ Staphylinidae	*Paederus fuscipes*	PR	0.13	0.07	1.33
Insecta/Diptera/Dolichopodidae	*Condylostylus* sp.	PR	0.00	0.23	1.73
Insecta/Diptera/Syrphidae	*Ischiodon scutellaris*	PR	0.00	0.03	0.57
Insecta/Diptera/Syrphidae	*Helophilus fasciatus*	PR	0.00	0.00	2.83
Insecta/Hemiptera/Anthocoridae	*Cardiastethus fascilientris*	PR	0.03	0.10	0.00
Insecta/Hemiptera/Reduviidae	Reduviidae (unidentified species A)	PR	0.00	0.00	0.20
Insecta/Hemiptera/Pentatomidae	*Andrallus spinindens*	PR	0.10	0.00	0.13
Insecta/Odonata/ Coenagrionidae	Coenagrionidae (unidentified species A)	PR	0.00	0.00	0.03
Arachnida/Araneae/Linyphiidae	*Bathyphantes* sp.	PR	0.13	0.13	0.00
Arachnida/Araneae/Oxyopidae	*Oxyopes javanus*	PR	0.23	0.23	0.10
Arachnida/Araneae/Oxyopidae	*Oxyopes variabilis*	PR	0.13	0.00	0.00
Arachnida/Araneae/Oxyopidae	*Oxyopes macilentus*	PR	0.03	0.10	0.13
Arachnida/Araneae/Tetragnathidae	*Thomisus* sp.	PR	0.07	0.00	0.37
Arachnida/Araneae/Theridiidae	*Theridion* sp.	PR	0.03	0.00	0.00
Arachnida/Araneae/Araneidae	*Argiope* sp.	PR	0.00	0.03	0.17
Arachnida/Araneae/Araneidae	*Araniella* sp.	PR	0.00	0.13	0.00
Arachnida/Araneae/Araneidae	Araneidae (unidentified species A)	PR	0.03	0.50	0.17
Arachnida/Araneae/Lycosidae	*Pardosa pseudoannulata*	PR	0.00	0.00	0.07
The number of species of PR			**17.00**	**13.00**	**20.00**
The abundance of PR			**4.50**	**3.60**	**11.90**
Insecta/Coleoptera/Coccinellidae	*Henosepilachna* sp.	HV	0.13	0.00	0.07
Insecta/Coleoptera/Chrysomelidae	*Aulacophora indica*	HV	0.00	4.63	0.47
Insecta/Coleoptera/Chrysomelidae	*Aulacophora dorsalis*	HV	0.00	0.00	0.30
Insecta/Coleoptera/Chrysomelidae	*Phaedon cochleariae*	HV	0.00	0.00	0.10
Insecta/Coleoptera/Chrysomelidae	*Altica* sp.	HV	0.00	2.93	0.00
Insecta/Hemiptera/Alydidae	*Leptocorisa acuta*	HV	0.00	0.03	0.10
Insecta/Hemiptera/Cicadelidae	*Empoasca* sp.	HV	2.30	2.77	1.07
Insecta/Hemiptera/Aphididae	*Aphis gosypii*	HV	7.93	4.63	5.80
Insecta/Hemiptera/Pentatomidae	*Nezara viridula*	HV	0.33	0.00	0.00
Insecta/Hemiptera/Aleyrodidae	*Aleurodicus dugesii*	HV	5.90	0.00	0.00
Insecta/Lepidoptera/Nymphalidae	*Acraea violae*	HV	0.13	0.00	0.00
Insecta/Orthoptera/Acrididae	*Tetrix* sp.	HV	0.07	0.27	0.13
Insecta/Orthoptera/Acrididae	*Dissosteira carolina*	HV	0.00	0.10	0.00
Insecta/Orthoptera/Acrididae	*Valanga nigricornis*	HV	0.07	0.20	0.40
The number of species of HV			**8.00**	**8.00**	**9.00**
The abundance of HV			**16.87**	**15.57**	**8.43**
Insecta/Hymenoptera/Sphecidae	*Sceliphron* sp.	PA	0.23	0.07	0.00
Insecta/Hymenoptera/Braconidae	*Apanteles* sp.	PA	0.13	0.03	0.03
Insecta/Hymenoptera/Braconidae	*Cotesia* sp.	PA	0.07	0.00	0.00
The number of species of PA			**3.00**	**2.00**	**1.00**
The abundance of PA			**0.43**	**0.10**	**0.03**
Insecta/Diptera/Muscidae	*Musca domestica*	NI	0.07	0.00	0.00
Insecta/Diptera/Lauxaniidae	*Homoneura* sp.	NI	0.00	0.03	1.03
Insecta/Diptera/Calliphoridae	*Calliphora* sp.	NI	0.00	0.03	0.47
Insecta/Diptera/Chironomidae	*Chironomus* sp.	NI	0.00	0.20	0.00
Insecta/Hymenoptera/Formicidae	Formicidae (unidentified species A)	NI	0.90	0.53	0.07
Insecta/Hymenoptera/Formicidae	Formicidae (unidentified species B)	NI	0.83	0.00	0.00
The number of species of NI			**3.00**	**4.00**	**3.00**
The abundance of NI			**1.80**	**0.80**	**1.57**
The total number of species			**31.00**	**27.00**	**33.00**
The total of abundance			**23.60**	**20.07**	**21.93**

Note: PR: predatory arthropods, HV: herbivorous insects, PA: parasitoids, NI: neutral insects, A: plot with leaf litter mulch, B: plot with plastic mulch, C: weedy plot without mulch

Table 3. Arboreal arthropod assemblages (community of predatory arthropods, herbivorous insects, parasitoids, and neutral insects) found in three chili fields with different management practices

Guilds	Community characteristics	A	B	C
Predatory arthropods	Abundance (individual/5 nets)	4.47	3.60	11.93
	Biodiversity index (H')	2.13	2.12	2.44
	Dominance index (D)	0.32	0.29	0.24
	Evenness index (E)	0.75	0.83	0.81
Herbivorous insects	Abundance (individual/5 nets)	16.87	15.57	8.43
	Biodiversity index (H')	1.19	1.50	1.15
	Dominance index (D)	0.47	0.29	0.69
	Evenness index (E)	0.57	0.72	0.52
Parasitoids	Abundance (individual/5 nets)	0.43	0.10	0.03
	Biodiversity index (H')	0.98	0.64	0
	Dominance index (D)	0.54	0.60	1.00
	Evenness index (E)	0.90	0.92	0
Neutral insects	Abundance (individual/5 nets)	1.80	0.80	1.57
	Biodiversity index (H')	0.83	1.24	0.66
	Dominance index (D)	0.50	0.67	0.66
	Evenness index (E)	0.75	0.77	0.47

Note: A: plot with leaf litter mulch, B: plot with plastic mulch, C: weedy plot without mulch

Figure 2. Dominant predatory arthropod species found in the chili canopy: A. *Oxyopes macilentus*, B. *Oxyopes variabilis*, C. *Thomisus* sp., D. *Pardosa pseudoannulata*, E. *Condylostylus* sp., F. *Harmonia octomaculata*, G. *Menochilus sexmaculatus*, H. *Harmonia* sp., I. *Coelophora inaequalis*, J. *Arisolemma dilatata*, K. *Menochilus sexmaculatus* larvae, L. *Micraspis inops* adult, M. *Micraspis discolor*, N. *Micraspis* sp., O. *Paederus fuscipes*, P. *Ischiodon scutellaris* larvae, Q. *Ischiodon scutellaris* adult, R. *Andrallus spinindens*, S. *Cicindela* sp.

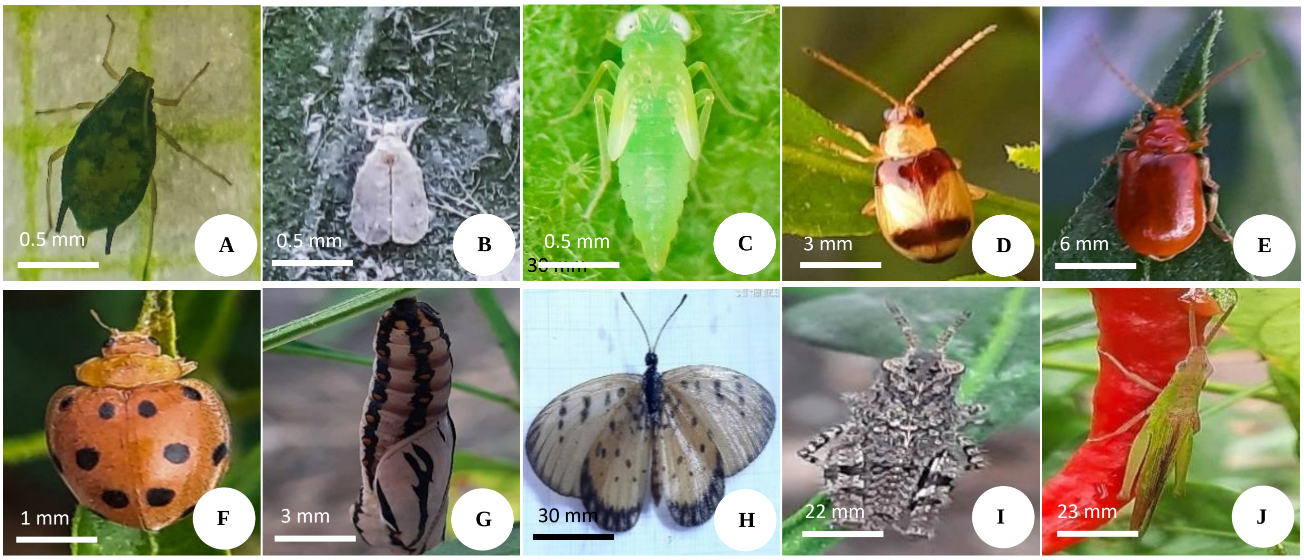


Figure 3. Dominant herbivore species found in the chili canopy: A. *Aphis gosypii*, B. *Aleurodicus dugesii*, C. *Empoasca* sp., D. *Aulacophora dorsalis*, E. *Aulacophora indica*, F. *Henosepilachna* sp., G. *Acraea violae* pupae, H. *Acraea violae* adult, I. *Tetrix* sp., J. *Valanga nigricornis*

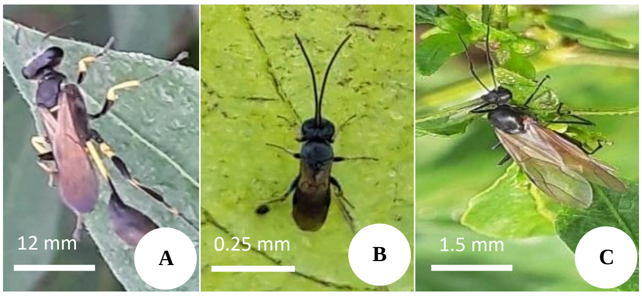


Figure 4. Parasitoid species found in the chili canopy: A. *Sceliphron* sp., B. *Apanteles* sp., and C. *Cotesia* sp.

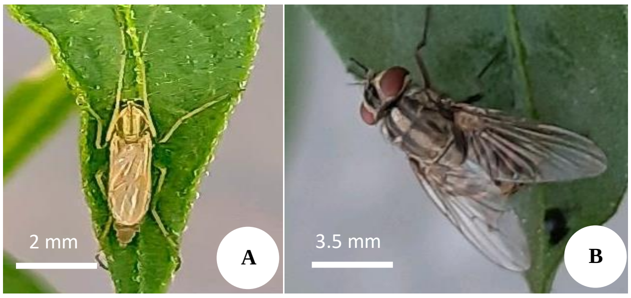
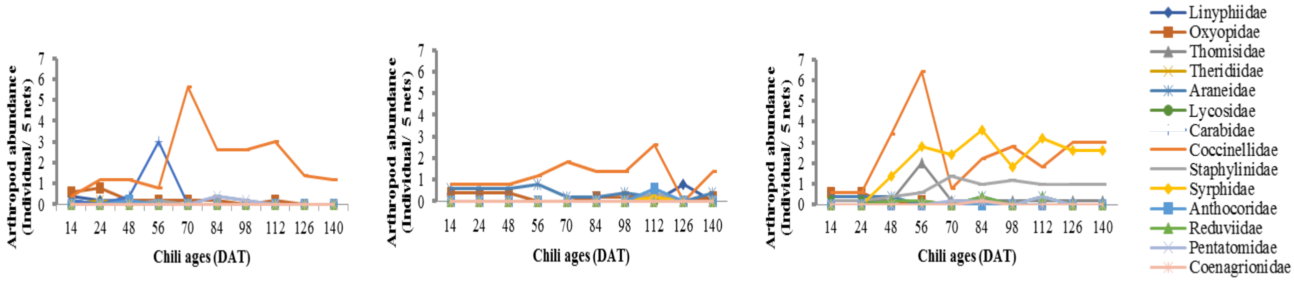
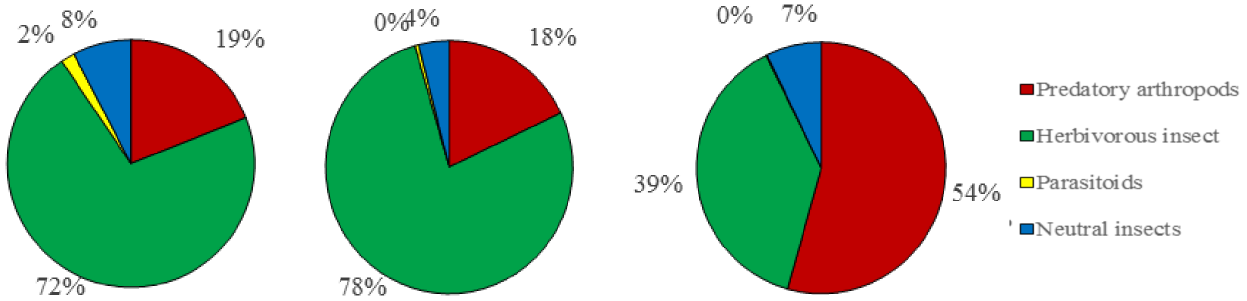


Figure 5. Neutral insect species found in the chili canopy: A. *Chironomus* sp., B. *Musca domestica*



A **B** **C**

Figure 6. A. The abundance of predatory arthropods in plot with leaf litter mulch, B. Plot with plastic mulch, C. Weedy plot without mulch



A **B** **C**

Figure 7. The proportion of the arboreal arthropod guilds in: A. Plot with leaf litter mulch, B. Plot with plastic mulch, C. Weedy plot without mulch

Discussion

In this study, many species of the predatory arthropod were found, including *P. pseudoannulata, H. octomaculata, M. sexmaculatus, C. inaequalis, A. dilatata, M. inops, P. fuscipes, I. scutellaris,* and *A. spinindens*. The most dominant predatory insect families were Coccinellidae and Syrphidae, while the most dominant spiders were Oxyopidae. They were generalist predators or polyphagous predators being able to prey on various insect species from several families. *P. pseudoannulata* can attack *A. gosypii, A. dugesii, Empoasca* sp., *Bemisia tabaci* (Jiang et al. 2020). Coccinellid beetles, such as *M. sexmaculatus,* are generalist predators that can attack *A. gosypii, Empoasca* sp., *Bemisia tabaci* (Bhatt et al. 2018). In this study, *Aulacophora dorsalis* and *Aulacophora indica* were also found which were the prey of generalist predators. The generalist predators have been reported to attack various species of *Aulacophora* spp. (Pal et al. 2017). *A. dorsalis* and *Aulacophora indica* generally attack cucumber leaves, but in this study, they were found to attack chili leaves because the cucumbers were planted around the chilies.

From the data on the species diversity and abundance of the arboreal predatory arthropods, the highest was found in location C, while the lowest was at location B. Location C was a plot that did not use mulch and the application of synthetic insecticides was only at the beginning of planting, while location B used the plastic mulch and routine synthetic insecticide applications. The species diversity and abundance of predatory arthropods were higher at location C because that location had relatively more niches than those at locations B and C because the microhabitats were provided by the wild plants that were still let to grow in the weedy chili field. According to Anggraini et al. (2021), non-crop plants are preferred by the predatory arthropods for alternative habitats over crops. The diversity of non-crop plants provides more prey and alternative habitats (Parry et al. 2015). Spraying the synthetic insecticides at location C did not reduce the number of species and abundance of predatory arthropods. The spraying was only carried out at the beginning of planting when the chilies were 14, 21, and 28 days after planting. However, the high doses and frequency of synthetic insecticide applications carried out at location B on a scheduled basis every week starting from 7 days after planting until ahead of harvest caused the number of species and abundance of predatory arthropods in location B to be the lowest. According to Hanif et al. (2020), overdose of synthetic insecticides can cause a decrease in the abundance and species diversity of predatory arthropods.

At location A, the species diversity and abundance of predatory arthropods were lower than those at location C. However, the number of species and abundance of spiders were higher at location A than those at locations B and C. Location A used leaf litter mulch and bioinsecticide and the weeds were always weeded. The presence of the leaf litter mulch causes a greater number and abundance of spiders at location A compared to those at locations B and C. The leaf litter provides habitats and shelters for hunting spiders (Potapov et al. 2020). Consequently, location A was suitable for habitats, shelters for the spiders. At location C, the hunting spider, *P. pseudoannulata* were found, while in locations A and B they were not found. This is because location C was surrounded by ~ 300 ha of paddy which was the spider's natural habitat. *P. pseudoannulata* is a generalist predator with its main prey being paddy pests, such as the brown planthopper, *Nilaparvata lugens* (Daravath and Chander 2017). The presence of generalist predators, such as *Pardosa* spp. are beneficial in suppressing the population of important chili pests, such as *Thrip tabaci* and *B. tabaci* (Mohsin et al. 2015). The position of the chili location adjacent to the paddy field is advantageous for chili because of the flow of generalist predatory species from the paddy plants, while the important pests of paddy do not migrate because they include monophagous and oligophagous species whose host plants are not chilies.

The herbivorous insects predominant in all locations were the family of Aphididae. At location C, the population of the herbivorous insects was found to be the lowest possible because the role of generalist predators functioned well. Based on the data on the abundance of predatory arthropods, the most abundant one at location C was an indicator that the predatory arthropods settled and functioned to suppress the population of the herbivorous insects. At locations A and B, the population of the herbivorous insects was high possibly due to the abundance and low diversity of generalist predator species. At location B using plastic mulch, *A. gosypii* and *Empoasca* sp. were the key pests on chilies. From the data of this study, the plastic mulch was not able to suppress the presence of *A. gosypii* and *Empoasca* sp. However, plastic mulch can reduce the population of chili pest species, such as *T. tabaci* and *B. tabaci* (Karungi et al. 2013).

Only 3 parasitoid species were found, namely Sphecidae (unidentified species), Braconidae sp. A (unidentified species), and Braconidae sp. B (unidentified species). Sphecidae has a guild as a parasitoid (Borisade et al. 2017), but many species of the Sphecidae act as predators that prey on spiders thus consequently Sphecidae wasps could be intraguild predators of spiders (Carvalho et al. 2014). The hosts could not determine the three species they attacked because the sample was the adult stage of the parasitoids. Parasitoid species commonly found in chilies, such as *Diaeretiella rapae* (Pope et al. 2012) and *Aphidius* sp. (Majidpour et al. 2020) attacking A. gossypii were not found in this study. The presence of a high ant population (Formicidae) in chilies can be a biotic competitor that disrupts and repels the presence of parasitoids and predators (Zhou 2014) and consequently A. gossypii was dominant.

Several species of neutral insects found in this study such as *Chironomus* sp., *Calliphora* sp. and *Homoneura* sp. were required for ecosystem services to serve as alternative preys for generalist predators. According to Karenina et al. (2020b), *Chironomus* sp. and many other neutral insect species are very supportive of maintaining the presence of generalist predators because when the herbivorous insects decline in population in plants, their availability in wild plants can become alternative prey. Sometimes generalist predators prefer neutral arthropods more than herbivorous pests. Thus, the presence of alternative preys not always beneficial.

Interesting information about the proportion between guilds, the predatory arthropods were the most dominant at location C compared to other guilds (the herbivorous insects, parasitoids, and neutral insects) by occupying more than 50% of the location. At locations A and B, they were dominated by the herbivorous insects more than 70% compared to other guilds. Location C was more suitable for predatory arthropods than the other locations, possibly due to the weedy vegetation which provided alternative microhabitats. Processes in the chili ecosystem at location C, such as food chains, worked well as indicated by the diversity of species and the dominance of the predatory arthropods higher than the dominance of prey (the herbivorous insects and neutral insects). According to Riggi and Bommarco (2019), diverse and dense plants support the abundance and species diversity of generalist predators and their prey and cause food chains to be strong and stable.

In conclusion, the chili field with the weedy plot without mulch had the highest species biodiversity and abundance of arboreal predatory arthropods, while the chili field of synthetic insecticides and plastic mulch has the lowest predatory abundance. The herbivorous insects in the chili field that apply synthetic insecticides and plastic mulch and the leaf litter mulch are higher than in the chili field without mulch. In the chili field that applied the leaf litter mulch and bioinsecticide, the number of species and the abundance of the spider assemblage was the highest compared to the other fields. Thus, the chili field without mulch and the leaf litter mulch is ideal habitat for the arboreal predatory arthropods.

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