Arthropod diversity in ramie (*Boehmeria nivea* (L.) Gaudich) plantation

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**Abstract.** Understanding the diversity of arthropods in a crop ecosystem could be used as a basis to develop pest management in the crop cultivation. The insect pest management system for ramie has not been developed intensively in Indonesia. Therefore, this study aimed to evaluate the diversity of arthropods associated with ramie plantation. The research was done using a survey method in ramie plantations at Wonosobo, Central Java from August 2020 to March 2021. The survey method applied was direct and indirect observations. Direct observations were made visually, and indirect observations was using traps and sweep-nets. Observations were done at the age of plants 1-8 weeks. The results showed that arthropods associated with ramie plantations belong to eight orders, 26 families, and 45 species which were as herbivores, parasitoids, predators, pollinators, and decomposers. The diversity index was in the high category ($H' = 3.08 – 3.47$), and the community evenness index was in the stable category ($E = 0.81-0.93$). Insects with herbivorous status had not caused significant damage to the plants, so that the ramie plantation in Wonosobo did not need any insect pest control actions.

**Keywords:** insect pest management, bast fibre; herbivore, parasitoid, predator

1. **Introduction**

Ramie (*Boehmeria nivea*) is an annual herbaceous plant from the Urticaceae family that produces fiber from its bast. Ramie fiber has the character of natural fiber, high fiber strength, and high cellulose content. The other characters of ramie fibers are hygroscopic, fine textured, and bright white color, so they are very suitable for use as textile materials and textile products. Currently, ramie fiber is not only used as a textile raw material, but also as a raw material for making composites that are environmentally friendly [1], and have the potential to replace metals and plastics [2], as well as paper [3]. Ramie leaves have been utilized for feedstock [4, 5], and decortication waste can be utilized as an efficient substitute for inorganic fertilizers [6]. Even though the vast utilization potential of ramie fiber and biomass is extensive, and also as a sustainable agricultural production activity, this commodity, which is categorized as a plantation crop, has not been optimally developed in Indonesia. These caused studies on sustainable agriculture involving ramie are not extensively carried out in Indonesia, including basic studies on the diversity of arthropods associated with ramie, which is the basis for the development of pest management.

Ramie is easy to cultivate. In an optimal agroecosystem state with sufficient rainfall, ramie plants could be harvested every two months for approximately eight years cultivation. The existence of monoculture plantation throughout the year on a large expanse has the potential to cause an explosion ...
of non-harmful herbivorous insects into harmful herbivore insects or injurious insect pests [7]. With the potential for rami development that are increasingly intensive, there is a genuine concern that the insect pests will become a significant factor in the decline of rami fiber production, if the non-injurious insects are not appropriately managed. In order to avoid faults in making decisions on insect pest management on rami plantations, it is necessary to provide an environmentally friendly pest management technology by using an ecological approach.

Pest management with an ecological approach is principally a multidisciplinary approach to manage heviborous insect populations by utilizing various control methods that are compatible in one integrated management of arthropods in agroecosystems. Arthropods as components of biodiversity have an essential role in agricultural ecosystems with their status as herbivorous, parasitoids, predators, and bioindicators [8, 9, 10]. Herbivorous insects can cause crop yield loss, either directly eating plant tissue or as vectors of plant diseases. Parasitoids are insects that live as parasites in other insects and as a mortality factor of their host [11, 12]. Predators are arthropods that prey on insects which are generally smaller in than predator’s size [13, 14]. The existence of arthropods and the occurrence of trophic interactions will benefit the first trophic level (plants), if the diversity of arthropods in such an agroecosystem is in balance (15).

Research on arthropods associated with rami plantations in Indonesia has not been deeply studied, so that insect pest management strategies have not been developed intensively. Therefore, the study aim was to evaluate the diversity of arthropods associated with rami plantations and to understand the occurrence of trophic interactions in the plantations. The results of this study are projected to be useable for developing pest management strategy in an environmentally friendly and sustainable rami cultivation system.

2. Materials and method

The research was conducted in a commercial rami plantation in Kalikajar District, Wonosobo Regency, Central Java (7°21′54″S, 109°56′22″E, altitude 855 m asl) from August 2020 to March 2021. The monthly precipitation and temperature (minimum-maximum) were 61-415 mm and 23°-35°C during dry season; 514-715 mm and 25°-34°C during rainy season, respectively. Identification of arthropods and morphospecies insects was carried out on Entomology Laboratory of ISFCRI using available books and e-books of insect identification [16].

Surveys of arthropods associated with rami plantations were conducted in observation plots. Observations were done on the presence of arthropods associated with rami plantation directly (visually) and indirectly (using insect nets and traps). Observations were made at intervals of 2-4 weeks, which included observations during dry and rainy seasons in 2020 and 2021, respectively. Total number of observations during dry and rainy seasons were 4 and 6 times, respectively.

2.1. Direct observation

Sampling on direct observation was carried out on 25 observation units (1 unit = 1 m²) which were determined diagonally in rami plantation of 0.1-0.25 ha. The minimum distance of sample plant units from the edge of the plot and between sample plant units was 10 m. This direct observation was carried out on 2-3 observation plots of the same age of rami. Plant age referred to the age of the rami plants after cutting which were done every 8-10 weeks to obtain rami-bast fibers.

Collections of herbivorous insects in all stages were done to observe the parasitization of leaf-rolling larvae. The percentage of parasitization was calculated by recording the number of parasitized eggs/larvae/pupae from the total collected hosts. The emerged parasitoids were identified using [17].

2.2. Indirect observation

Observation of arthropods on the ground surface was carried out using insect nets (Ø 60 cm), in each sample plot, repeated 3 times, each of 20 swings. Observations of arthropods on the ground were carried out using pitfall traps and yellow pan traps. Pitfall traps are made of plastic cups (Ø 6 cm and height 12 cm), while the yellow pan trap is a yellow plastic bowl (Ø 15 cm and height 5 cm). Traps
were installed systematically with a distance 10 m from the edge of the plot, and 10 m between traps. Ten pitfall and yellow-pan traps were installed in each plot. The installation of pitfall traps was done by immersing the traps in the ground with the surface of the plastic cup flat on the ground; while the yellow pan traps were placed on the ground. The traps were filled with 1% detergent solution as much as one-third of the part and traps for 24 hours. Trapped arthropods in each trap were collected separately. Large insect specimens were ended into a dry collection, while small insects were set in slide collection using Hoyer's medium. Insect specimens from groups of ants, Collembola, and spiders were collected in 70% alcohol solution separately based on the observed differences in morphospecies. Collembola were identified using the classification of Hopkin [18].

2.3. Data analyses
The data obtained were evaluated by ANOVA to calculate the type and density of each arthropod species based on the time of observation, namely the rainy and dry seasons, and the age of the plant after cutting. The diversity of insects associated with ramie was analyzed using the diversity index developed by Shanon – Weaver [19, 20], with the following formula:

\[ H' = - \sum Pi \ln(Pi); \pi = (ni/N) \]

\( H' \) = Diversity index of Shannon-Wiener; \( ni \) = Number of individuals of species; \( N \) = Total number of all species. Criteria for diversity index value of Shanon – Wiener (\( H' \)):
- \( H'<1 \) = low diversity;
- \( 1<H'\leq3 \) = medium diversity;
- \( H'>3 \) = high diversity.

In order to calculate the species richness, index of eveness of Pielou (1966) was used,

\[ E = H' / \log S \]

\( E \) = the value of Shannon–Wiener index; \( S \) = number of species;

Based on eveness index, the species richness the community's structure could be interpreted as

Environmental community criteria based on evenness index:
- \( 0.00 < E < 0.50 \) depressed community
- \( 0.05 < E < 0.75 \) unstable community
- \( 0.75 < E < 1.00 \) stable community

3. Results and discussion
Identification of the sampled arthropods consisted of 6 orders of insects belong to 16 families and 38 species; 1 order of spiders consisting of 3 families and 4 morphospecies, and 2 families of springtails with 3 morphospecies; in a total of 45 species (Table 1). Identification of the collected Arthropods was engrossed on the insects’ groups. Identification of spiders and springtails only up to the morphospecies level within the family.

Determination of each species status was conducted by direct observation while counting the abundance of arthropods on sample plants, and by collecting information from existing references relating to the species in question. The status composition of the sampled Arthropods revealed that the composition of herbivorous arthropods (31.11%) was in balance with that of predators (31.11%) (Table 2). The composition values of natural enemies of herbivores, which consist of insect parasitoids (15.56%) and predators (31.11%), exceeded the composition value of herbivores (31.11%).
Table 1. Diversity of arthropod species collected from direct observation, sampling with sweeps net, pitfall traps, and yellow-pan traps from rami plantations in Wonosobo on August 2020 - March 2021.

| Classification | Common Name | Arthropods collected from sampling by | Status |
|----------------|-------------|--------------------------------------|--------|
|                |             | Visual observation | Sweep net | Pitfall trap | Yellow-pan trap |        |
| **Ordo Areaneida** |             |                        |          |                    |                    |        |
| 1. Family Lycosidae | Wolf spider | + (A)                  | -        | + (A)              | + (A)              | Pr     |
| - Species 1      |             |                        |          |                    |                    |        |
| 2. Family Tetragnathidae | long jawed spiders | -                    | +        | -                  |                    | Pr     |
| - Species 1      |             |                        |          |                    |                    |        |
| 3. Family Thomisidae | Crab spider | + (A)                  | + (A)    | -                  | -                  | Pr     |
| - Species 1      |             |                        |          |                    |                    |        |
| - Species 2      |             |                        |          |                    |                    |        |
| **Ordo Coleoptera** |             |                        |          |                    |                    |        |
| 1. Family Curculionidae | Ash weevil | +++ (A)                | + (A)    | -                  | -                  |        |
| - Myllocerus sp. |             |                        |          |                    |                    |        |
| 2. Family Coccinellidae | Six-spotted zigzag ladybird | ++ (A)           | + (A)    | -                  | -                  | Pr     |
| - Chelomomenes sexmaculata |       |                        |          |                    |                    |        |
| - Epilachna sp. |             |                        |          |                    |                    |        |
| 3. Family Chrysomelidae | Flea Beetle | + (A)                  | + (A)    | -                  | -                  | H      |
| - Nisotra sp. |             |                        |          |                    |                    |        |
| - Pachnephorus bretinghami | Leaf-eating beetle | + (A)            | + (A)    | -                  | -                  | H      |
| 4. Family Staphylinidae | Rove beetles | + (A)                  | -        | -                  | -                  | Pr     |
| - Oxytelus sp. |             |                        |          |                    |                    |        |
| - Paederus sp. |             |                        |          |                    |                    |        |
| **Ordo Diptera** |             |                        |          |                    |                    |        |
| 1. Family Assilidae | Robber fly | + (A)                  | +        | -                  | -                  |        |
| - Asilus sp. |             |                        |          |                    |                    |        |
| 2. Family Dolichopodidae | Green-blue Long-legged Fly | -            | + (A)    | -                  | -                  | Pr     |
| - Species 1      |             |                        |          |                    |                    |        |
| - Species 2      |             |                        |          |                    |                    |        |
| **Ordo Hemiptera** |             |                        |          |                    |                    |        |
| 1. Family Cicadellidae | Leathopper | ++ (N, A)              | +        | +                  | -                  | H      |
| - Amrasca biguttula |             |                        |          |                    |                    |        |
| - Empoasca bifurcata | Leathopper | ++ (N, A)             | +        | +                  | -                  | H      |
| 2. Family Pentatomidae | Green stink bug | + (A)            | +        | -                  | -                  | H      |
| - Nezara sp. |             |                        |          |                    |                    |        |
| **Ordo Hymenoptera** |             |                        |          |                    |                    |        |
| 1. Family Formicidae | Parrot ants | -                    | -        | ++ (W)             | ++ (W)             | Pr     |
| - Nylanderia sp.1 |             |                        |          |                    |                    |        |
| - Nylanderia sp.2 | Carpenter ants | ++ (W)        | -        | -                  | -                  | Pr     |
| - Camponotus sp. |             |                        |          |                    |                    |        |
| - Polyrhachis sp. |             |                        |          |                    |                    |        |
| 2. Family Apidae | Eastern honey bee | + (A)          | -        | + (A)              | -                  | P      |
| - Apis cerana |             |                        |          |                    |                    |        |
| - Apis mellifera | Western honey bee | -          | -        | + (A)              | -                  | P      |
| 3. Family Braconidae | Parasitoid wasp | + (A)          | + (A)    | -                  | -                  | Pa     |
| - Apanteles sp. |             |                        |          |                    |                    |        |
| 4. Family Chalcididae | Parasitoid wasp | + (A)          | + (A)    | -                  | -                  | Pa     |
| - Brachymycria sp |             |                        |          |                    |                    |        |
| - Species 1 |             |                        |          |                    |                    |        |
| **Ordo Eulopidae** |             |                        |          |                    |                    |        |

4
Herbivores associated with ramie plants generally consumed leaves, for example, the larvae of *A. issora* and *Pleuroptya* sp. or flea beetle adults, *Nisotra* sp. Consumption of herbivores on plant parts that are not the expected product of bast fiber cultivation activities caused these herbivorous insects

Collembola and several species of Diptera were arthropods that act as decomposers; while pollinators are only from a Hymenopteran family, namely Apidae.

### Table 2. Status composition of Arthropods species in ramie plantations in Wonosobo in August 2020 – March 2021.

| Order            | Decomposer | Herbivore | Polinator | Parasitoid | Predator |
|------------------|------------|-----------|-----------|------------|----------|
| Arachneida       | 0.00       | 0.00      | 0.00      | 0.00       | 11.11    |
| Coleoptera       | 0.00       | 11.11     | 0.00      | 0.00       | 6.67     |
| Colembola        | 6.67       | 0.00      | 0.00      | 0.00       | 0.00     |
| Diptera          | 4.44       | 0.00      | 0.00      | 0.00       | 4.44     |
| Hemiptera        | 0.00       | 6.67      | 0.00      | 0.00       | 0.00     |
| Hymenoptera      | 0.00       | 0.00      | 6.67      | 15.56      | 8.89     |
| Lepidoptera      | 0.00       | 6.67      | 0.00      | 0.00       | 0.00     |
| Orthoptera       | 0.00       | 6.67      | 0.00      | 0.00       | 0.00     |
| **Total (%)**    | **11.11**  | **31.11** | **6.67**  | **15.56**  | **31.11** |

Note: Values are in percentage (%).

Among the arthropods, Hymenopteran species had the status of valuable insects, namely as pollinators and natural enemies of herbivores (i.e., parasitoids and predators). The composition value of species between herbivores and their natural enemies was in balanced. This would explain that ramie cultivation in Wonosobo, which has existed for more than 5 years, has never experienced an outbreak of herbivore population that caused a decrease in fiber production.

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not to be called insect pests, although it was reported by Selvaraj et al. [21] that Indian-red-admiral caterpillar, *Vanessa indica*, (Lepidoptera: Nymphalidae) can cause up to 50% damage. In addition, a co-species of leaf folder associated with ramie in Wonosobo, namely *Pleuroptya ruralis*, was reported as an insect pest that caused up to 80% damage to soybeans in Japan [22]. The parasitization rate of *Pleuroptya* sp. which infested ramie plants in Wonosobo by *Apanteles* sp. was less than 2%. This indicated that despite the position of the larvae in leaf rolls, which may avoid predation, parasitoids can be an important biotic mortality factor, so that natural control by their biotic mortality factors causes their infestation in ramie plants at a level that is not detrimental, even though the host plant is available throughout the year.

The number of individual arthropods species included in groups of insects, spiders and springtails in the dry season (August – October 2020) and in the rainy season (October 2020 – March 2021) did not differ (Table 3). This indicated that the condition of ramie agroecosystem was stable. This state was supported by good ramie cultivation practice, especially in pest management that relied on the acts of natural enemies.

Table 3 showed that the abundance of arthropod populations in ramie plantations in dry and rainy seasons was differed for certain insect groups. For example, ants, bees, and wasps are more numerous during the rainy season than during the dry season. In contrast, groups of springtails, crickets, grasshoppers, and ladybugs were more commonly abundant during the dry season than during the rainy season. This phenomenon is related to the support of abiotic environmental conditions, especially temperature and humidity. During the dry season, the temperature was relatively higher and the humidity was lower than those in the rainy season. These arthropod groups have different responses to environmental conditions. The activity of worker ants *Selenopsis invicta* was negative hydrokinetic, meaning that in humid conditions, their activity was reduced [23]. In contrast, European bee pollinators have high mortality in conditions with low humidity [24].

Table 3. The number of individuals (Mean ± Standard Error) of arthropods in ramie plantations in Wonosobo during the dry season (August-October 2020) and the rainy season (October 2020-March 2021).

| Arthropods                        | Dry Season | Rainy Season |
|-----------------------------------|------------|--------------|
| Hymenoptera (ants, bees and wasps)| 12 ± 1.5   | 79 ± 4.7     |
| Collombola (springtails)          | 346 ± 1.7  | 50 ±0.6      |
| Coleoptera (weevils, rove beetles, ladybeetles) | 508 ± 56.5 | 898 ± 44.7   |
| Orthoptera (grasshoppers and crickets) | 284 ± 3.1  | 105 ± 2.3    |
| Diptera (flies)                   | 57 ± 1.7   | 41 ± 1.5     |
| Araneae (spiders)                 | 628 ± 72.5 | 654 ± 0.6    |
| Hemiptera (green stink bugs, leafhoppers, flea hoppers) | 22 ± 1.7   | 8 ± 1.7      |
| Lepidoptera (army worms, leaf folder, yellow coasters) | 64 ± 1.6   | 83 ± 5.0     |

*Note: Sampling was done by using pitfall traps, yellow-pan traps, and net-sweeping.*

Table 4. Diversity and Evenness indices of arthropod associated with ramie plantation in Wonosobo from sampling on August 2020 – March 2021 based on Shannon-Wiener Index.

| Indeces                                | Plant Age (weeks after cuttings) |
|----------------------------------------|----------------------------------|
|                                        | <3  | 3-6 | >6  |
| Diversity Index (H')                   | 3.47| 3.18| 3.08|
| Evenness Index (E)                     | 0.93| 0.85| 0.81|
Species diversity is a characteristic of a community-level and could express community structure. Species diversity would also be used to measure community stability, namely the ability of a community to maintain its stability, despite the occurrence of disturbances to its components. Based on the results of the arthropods sampling at different plant ages (Table 4), the diversity and evenness indices of the arthropods were not significantly different and all of them referred to the criteria for a high diversity with a stable community. This was in line with the individual’s number during the surveys on dry and rainy seasons, which showed no different values.

4. Conclusion
The diversity of arthropods in ramie plantations was in the high category. The arthropods’ community in ramie plantations was stable, even though it experienced disturbances, i.e., every 6-8 weeks the plants were cut down for ramie fiber production. The composition of herbivorous arthropods and their natural enemies associated with ramie plants in Wonosobo were in balance.

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