Diversity and abundance of arthropods inhabiting peat soil in monoculture and polyculture of balangeran (*Shorea balangeran*) plantation in South Sumatra, Indonesia

S Utami, I Muslimin, A Kurniawan, F Azwar, and Purwanto

Environment and Forestry Research and Development Institute of Palembang, Indonesia

E-mail: uut_balittaman@yahoo.com.

ABSTRACT. Arthropods have essential roles in the forest ecosystem; they act as herbivores, carnivores and detritivores in the food webs. This study aimed to analyze the diversity and abundance of arthropods inhabiting peat soil both in monoculture and polyculture plantation of balangeran (*Shorea balangeran*). The research was conducted in Riding Village, Ogan Komering Ilir District, South Sumatra, through an observation approach with pitfall trap and sweep nets, followed by selection and morphological identification. The identified arthropods were from 10 orders, and 24 families with the highest number of individuals belonged to the Formicidae family. The arthropods were classified mostly as predators (43.64%), closely followed by phytophag (38.18%), and the rest were parasitoid (14.54%) and pollinator (3.64%). The diversity index of arthropods under balangeran plants mixed with paddy and mixed with cajuput were 0.78, 0.65, and 0.93, respectively. The highest abundance of arthropods was found on balangeran plants mixed with paddy crop. These results revealed that planting systems have significant effects on diversity and abundance of peat soil arthropods.

1. Introduction
   1.1. Background
   The *Shorea balangeran* (Korth.) Burk (Balangeran) is a member of *Dipterocarpaceae* that naturally grows in peat swamp areas. Balangeran is one of the commercial tree species which is generally found in groups. Its wood has a high economic value as it has a durable class II, strong class II, and has a density of 0.86 [1]. The balangeran wood does not usually shrink when dried, and it is also resistant to the weathering fungi [2]. Balangeran wood is used for beams and boards in residential buildings, bridges, keelboats, magnetic bearings, and poles.

   Along with uncontrolled exploitation activities to meet market demand, this species is increasingly scarce and difficult to find. *S. balangeran* is categorized as critically endangered, according to the International Union for Conservation of Nature and Natural Resouces (IUCN) [3]. This plant is categorized as critically endangered, and it needs to be cultivated through rehabilitation activities and the development of forest plantation.

   In the burnt peatland area in Ogan Komering Ilir (OKI) Regency of South Sumatra Province, the planting of monoculture and mixed species of balangeran was conducted (with eucalyptus and paddy) in 2018. The same area was also used to rehabilitate forest plants to conserve the existence of natural...
enemies for plant pests and diseases on peatlands. The planting of Balangeran trees with other plants, along with their undergrowth vegetation, can be a place of life for arthropods as habitat, to find food, or to breed. The life of arthropods is very dependent on the presence and density of the population [4, 5]. These two factors are highly dependent on environmental factors, both biotic and abiotic. Arthropods play various roles in the food web as herbivores, carnivores, detritivores, and plays a role in the process of decomposition of land [6]. Arthropods act as natural enemies for pests that attack several forest plants. Therefore, if the forest ecosystem can be maintained, the presence of arthropods can be utilized and used as a counterweight in controlling pests and other disturbing organisms.

At present, data and information regarding the abundance and diversity of arthropods found in peat ecosystems are very limited. Therefore, a study to examine the existence and abundance of arthropods in peat ecosystems is crucial in considering the preservation of arthropods and their use as the controllers of forest plant pests.

1.2. Research objective
This research aimed to assess the diversity and abundance of arthropods, diversity of undergrowth vegetation, and the influence of undergrowth vegetation to the presence of arthropods on the peat soil surface under monoculture and polyculture Balangeran stands in the Riding Village of Pangkalan Lampam District, Ogan Komering Ilir Regency, South Sumatra Province.

2. Method and Materials
2.1. Time and location
The research was conducted in the Riding Village of Ogan Komering Ilir Regency, South Sumatra Province, from November 2018 to April 2019. The coordinates of the research locations were -3°6'42" SL and 105°12'49" EL (Figure 1), with an altitude of 22.1 m asl.

![Figure 1. Research location map in Ogan Komering Ilir, South Sumatra.](image)

2.2. Arthropods sample collection
Arthropods on the surface of the peat soil under monoculture and mixed planting of Balangeran (Balangeran-paddy and Balangeran-cajuput) were sampled using a pitfall trap. Balangeran planting in both monoculture and polyculture cropping patterns was carried out at the same time. Retrieval of arthropods on the ground using a pitfall trap such as in the Whitcomb method [7, 8]. The trap hole
was made of a plastic cup with a diameter of 6 cm and a depth of 15 cm in which one-third of the volume was filled with 70% alcohol solution.

The pit was installed on the surface of the ground and made sure that the surface was flat with the surrounding surface. The pit was covered with mica plastic with a pole 15 cm high from the ground. Three trap holes were installed in each location per observation. The position of the traps was arranged to spread evenly at the observation location. The traps were installed two and three months after balangeran trees were planted in December 2018 and January 2019, respectively.

Trapped arthropods were filtered with a tea filter and rinsed with running water. They were then put in a film tube containing 70% alcohol to be identified in the laboratory.

2.3. Arthropods identification
Each type of arthropod obtained was affixed to the cardboard with a needle. Then the specimens were inserted into the specimen box and photographed for documentation. All arthropods obtained in the field were subsequently identified. The identification results were then tabulated and analyzed. The identification of arthropods obtained from the field was carried out using reference books according to [9] and [10].

2.4. Undergrowth vegetation analysis
Three replications of 1 x 1 m² sized sampling plots were observed for each Balangeran plantation pattern to obtain undergrowth vegetation data. Sampling plots where insect pitfall trap plots were placed were also observed. Undergrowth vegetation in the sampling plot was identified and each species was quantified.

2.5. Data analysis
Composition data of family, species, and individual arthropods numbers were used to analyze arthropods abundance and diversity. Diversity measures in this study included the Shannon species diversity index, Berger-Parker domination species index, and Pielou species equality index by Maguran's book [11]. Sorensen index in Ludwig and Reynold's book [12] was used to compare arthropods community similarity in each tree stand.

Undergrowth vegetation data were compiled and analyzed to find out their relative density, relative frequency, and Important value index based on Pandeya [13].

3. Results and Discussion
3.1. The arthropods diversity on the peat surface under the S. balangeran
Based on the identification results, there were three classes of arthropods found, namely the Insecta (insect) class, the Araneae (spider), and mite classes (Table 1 and Table 2). The abundance of arthropods on peat soil surfaces under monoculture and polyculture balangeran plants at three months after planting were higher than two months after planting (Table 1 and Table 2). In two months after planting, the number of species found on the soil surface under the monoculture pattern (eight species) was lower than those on polyculture patterns with eucalyptus (10 species) (Table 1). A similar pattern was also observed three months after planting (Table 2).

### Table 1. The abundance of arthropods on the peat surface under monoculture and polyculture balangeran plants at two months after planting.

| Class, Ordo, dan Family | Balangeran + paddy | Balangeran + Cajuput | Balangeran |
|-------------------------|---------------------|----------------------|------------|
|                         | TS      | TI    | RD   | TS      | TI    | RD   | TS      | TI    | RD   |
| Insecta Lepidoptera     |         |       |      |         |       |      |         |       |      |
| Crambidae               | 1       | 2     | 15.38| 0       | 0     | 0    | 0       | 0     | 0    |
Table 2. The abundance of arthropods under monoculture and polyculture balangeran plants at three months after planting.

| Class, Ord, dan Family | Balanger + paddy | Balanger + Cajuput | Balanger |  |
|------------------------|------------------|-------------------|----------|---|
|                        | TS   | TI   | RD  | TS   | TI   | RD  | TS   | TI   | RD  |
| **Insecta**            |      |      |     |      |      |     |      |      |     |
| **Lepidoptera**        |      |      |     |      |      |     |      |      |     |
| Crambidae              | 0    | 0    | 0   | 0    | 0    | 0   | 1    | 3    | 3.89|
| Pyralidae              | 0    | 0    | 0   | 0    | 0    | 0   | 1    | 2    | 2.59|
| **Hymenoptera**        |      |      |     |      |      |     |      |      |     |
| Formicidae             | 2    | 35   | 56.45 | 1   | 29   | 29  | 4    | 37   | 48.05|
| Scolionidae            | 1    | 2    | 3.22 | 0    | 0    | 0   | 0    | 0    | 0   |
| Platygastridae         | 0    | 0    | 0   | 0    | 0    | 0   | 0    | 0    | 0   |
| Chalcididae            | 0    | 0    | 0   | 0    | 0    | 0   | 1    | 1    | 14.28|
| **Orthoptera**         |      |      |     |      |      |     |      |      |     |
| Acrididae              | 1    | 4    | 6.45 | 1    | 17   | 17  | 1    | 8    | 10.39|
| Grylidae               | 1    | 2    | 3.26 | 0    | 0    | 0   | 0    | 0    | 0   |
| **Hemiptera**          |      |      |     |      |      |     |      |      |     |
| Alydidae               | 0    | 0    | 0   | 0    | 0    | 0   | 1    | 2    | 7.14|
| **Coleoptera**         |      |      |     |      |      |     |      |      |     |
| Coccinellidae          | 2    | 8    | 12.90 | 2   | 17   | 17  | 2    | 6    | 7.79|
| Staphylinidae          | 1    | 1    | 1.61 | 1    | 3    | 3   | 0    | 0    | 0   |
| **Diptera**            |      |      |     |      |      |     |      |      |     |
| Culicidae              | 0    | 0    | 0   | 1    | 2    | 2   | 0    | 0    | 0   |
| Cecidomyiidae          | 1    | 4    | 6.45 | 1    | 5    | 5   | 0    | 0    | 0   |
| Tabanidae              | 0    | 0    | 0   | 2    | 4    | 4   | 0    | 0    | 0   |
| **Hemiptera**          |      |      |     |      |      |     |      |      |     |
| Pseudococcidae         | 0    | 0    | 0   | 1    | 6    | 6   | 0    | 0    | 0   |
| **Odonata**            |      |      |     |      |      |     |      |      |     |
| Coenagrionidae         | 0    | 0    | 0   | 1    | 1    | 1   | 1    | 1    | 1.29|
| **Araneae**            |      |      |     |      |      |     |      |      |     |
| Aracneidae             | 1    | 2    | 3.22 | 1    | 2    | 2   | 1    | 3    | 3.89|
| **Tungau**             |      |      |     |      |      |     |      |      |     |
In the observation of three months after planting, three classes of arthropods were found, namely insects, mites, and spiders. Whereas in the observation of two months after planting, only one class of arthropods, namely insects, were found. The numbers of orders found in all observation plots at two and three months after planting were seven orders (Lepidoptera, Hymenoptera, Orthoptera, Hemiptera, Coleoptera, Diptera, and Homoptera) and ten orders (Lepidoptera, Hymenoptera, Orthoptera, Hemiptera, Coleoptera, Diptera, Homoptera, Odonata, Araneae and Trombidiidae), respectively. The number of families found in the observation of three months after planting was higher than the one observed two months after planting, with the family type was almost the same in both monoculture and polyculture plots. Some families found in the pattern of monoculture and mixture of balangeran were Crambidae, Pyralidae, Formicidae, Scelionidae, Platygastridae, Chalcididae, Acrididae, Gryllidae, Alydidae, Aphididae, Coccinellidae, Staphylinidae, Culicidae, Cecidomyiidae, Tabanidae, Pseudococcidae, Coenagrionidae, and Trombidiidae.

Coccinellidae and Formicidae were the dominant families observed at two months and three months after planting, respectively. The relative densities of the family Formicidae in the balangeran plot, balangeran mixture with eucalyptus, and balangeran with paddy were of 48.05; 29, and 56.45, respectively (Table 2). The relative densities of the family Coccinellidae and Alydidae in balangeran stands with paddy were the same at 30.77 (Table 1). Formicidae was one family of social insects that were generally not destructive. Similarly, according to [14], Hymenoptera were grass eaters, and their movement was more flexible. The low number of observed families and individuals of the order of Orthoptera from balangeran monoculture plots might be due to the untimely sampling in the dry season as it would affect the presence of arthropods found. [15] reported that the presence of certain arthropods was strongly influenced by the season.

Differences in the abundance of individuals and species found in observation plots were caused by several factors, including the type of cultivated plants and undergrowth vegetation. The difference in cropping patterns had significant effects on the diversity of arthropods. It was reported that monoculture and polyculture affected terrestrial arthropods diversity [16]. The research by [4] showed that species composition was a key driver of forest biodiversity, influencing structural components of the environment from soil and litter to vegetation layers and the canopy, as well as ecosystem processes such as nutrient cycling [17]. Single species stands were typically homogenous in terms of habitat structure and the biotic communities supported. Polyculture stands might potentially support a greater array of species either through species-specific associations, which were directly influenced by the additional tree species [18].

Undergrowth vegetation, in the form of broadleaf weeds, grass, and ferns, is a habitat for arthropods where they find food and breed. An increasing variety of vegetation found under tree stands resulted in increasing diversity and abundance of arthropods. Diversity of undergrowth plants species in balangeran mixed plots with eucalyptus was higher than balangeran mixed plots with paddy and balangeran monoculture, both at observations of two and three months after planting (Table 3). Undergrowth plant species with the highest Important Value Index (IVI), *Paspalum conjugatum*, was at 87.96 when observed two months after planting, and 60.70 when observed three months after planting. *Clibadium sp.* is an undergrowth plant species that had the lowest IVI value of 9.72 in observation two months after planting, and 8.18 in observation three months after planting (Tables 3 and 4).

The high value of IVI represented high dominancy, which may have resulted in better adaptability than other species. According to [19], a type of vegetation affected the stability of the ecosystem because it is dominant from other types. IVI may reflect the role of a vegetation type in an area. The
type with higher IVI might have a more critical role in that area, as they may have more influence on the environmental condition and the existence of other species in the region [20].

The high diversity of undergrowth vegetation observed three months after planting influenced the abundance of arthropods found in balangeran plants. The variety of plantations might also have stimulated the growth of undergrowth vegetation, which affected the abundance of arthropods on the surface of peat soil.

**Table 3.** Diversity of undergrowth vegetation types on observation after two months of planting.

| Type of vegetation | Undergrowth vegetation | Important Value Index |
|--------------------|-------------------------|----------------------|
| B + P              |                         |                      |
| 1                  | Rumput japang           | 87.96                |
| 2                  | Kerisan                 | 41.67                |
| 3                  | Empriian                | 15.74                |
| 4                  | Rumput Mutiara          | 39.81                |
| 5                  | Pakis                   | 14.81                |
| B + C              |                         |                      |
| 1                  | Rumput kawat            | 18.52                |
| 2                  | Rumput paspalum         | 25.73                |
| 3                  | Rumput Mutiara          | 66.61                |
| 4                  | Kerisan                 | 18.52                |
| 5                  | Pakis                   | 37.67                |
| 6                  | Babandotan              | 10.98                |
| 7                  | Putihan                 | 9.72                 |
| 8                  | Empriian                | 12.23                |
| B                  |                         |                      |
| 1                  | Pakis                   | 47.56                |
| 2                  | Rumput japang           | 35.27                |
| 3                  | Babandotan              | 10.78                |
| 4                  | Rumput Mutiara          | 42.06                |
| 5                  | Rumput teki             | 11.53                |
| 6                  | Rumput kawat            | 29.08                |
| 7                  | Empriian                | 23.74                |

Note: B+P = balangeran + paddy; B+C = balangeran + cajuput; B = balangeran

**Table 4.** Diversity of undergrowth vegetation types on observation after two months of planting.

| Type of vegetation | Undergrowth vegetation | Important Value Index |
|--------------------|-------------------------|----------------------|
| B + P              |                         |                      |
| 1                  | Rumput japang           | 59.83                |
| 2                  | Alang-alang             | 10.57                |
| 3                  | Kerisan                 | 71.07                |
| 4                  | Semai spongol           | 9.45                 |
| 5                  | Empritan                | 10.58                |
| 6                  | Seduduk                 | 10.58                |
| 7                  | Resam                   | 18.44                |
| 8                  | Gelam (anakan)          | 9.45                 |
| B + C              |                         |                      |
| 1                  | Kerisan                 | 57.68                |
| 2                  | Empritan                | 15.94                |
| 3                  | Rumput kawat            | 14.50                |
| 4                  | Rumput Mutiara          | 42.06                |
| 5                  | Alang-alang             | 21.16                |
| 6                  | Resam                   | 38.55                |
| 7                  | Seduduk                 | 15.94                |
| 8                  | Rumput gajahan          | 8.41                 |
| 9                  | Rumput japang           | 11.89                |
The abundance of arthropods that were active on the ground surface based on tropic levels (Figures 2 and 3) showed that under a mixture of balangeran and cajuput, was the highest among plantation types. In the observations of months after planting, the number of predatory arthropods, herbivores, and parasitoids was more than those observed two months after planting (Figure 3). This showed that the increasing age of the plant increased the number of arthropods found. [15] reported that vegetation affected the diversity of animal species in certain plants. Besides that, the animal population was also influenced by water content, organic matter content, and soil temperature.

**Figure 2.** The abundance of predatory arthropods, herbivores, parasitoids, and pollinators under monoculture and polyculture balangeran at two months after planting.

**Figure 3.** The abundance of predatory arthropods, herbivores, parasitoids, and pollinators under monoculture and polyculture balangeran plants at three months after planting.
3.2. Diversity of Arthropods in two types of vegetation

The diversity index of active arthropods on the peat soil surface in balangeran and eucalyptus plants, which observed three months after planting, was the highest (0.97) among all cropping patterns. The high index of the diversity of arthropods that were active on the surface of the soil beneath balangeran plants with eucalyptus might occur due to the undergrowth vegetation and the higher density. The decrease in individual distribution may result in a decrease in the value of the species diversity index or arthropod species in the area.

Table 5. Diversity and abundance of peat soil arthropod communities under monoculture and mixed balangeran plants.

| Diversity and Abundance of Arthropods | Survey of 2 MAP | Survey of 3 MAP |
|--------------------------------------|-----------------|-----------------|
|                                      | B + P           | B + C           | B       |
| Abundance                            | 13              | 42              | 28      | 62      | 100   | 77    |
| Total of species                     | 5               | 10              | 8       | 11      | 15    | 14    |
| Index Shannon                        | 0.65            | 0.93            | 0.78    | 0.85    | 0.97  | 0.93  |
| Index Berger-Parker                  | 0.24            | 0.13            | 0.22    | 0.19    | 0.15  | 0.13  |
| Index Pielou                         | 0.40            | 0.41            | 0.37    | 0.36    | 0.36  | 0.38  |

Note: B = balangeran, P = paddy, C = cajuput

The dominance index of active arthropods on peat soil under the polyculture pattern of balangeran plants with paddy was highest (0.24) at both two and three months after planting (Table 5). The high degree of dominance of active arthropods on the ground surface in a mixture of balangeran with paddy showed an imbalance of populations between arthropod species. The evenness of active arthropod species in the balangeran mixed with eucalyptus pattern at two months after planting was highest (0.41) among all observations (Table 5). The high level of dominance and the low level of evenness of arthropod species in the ecosystem were also reported by Widiarta [21]. In this study, diversity, dominance, and evenness of arthropods were higher in polyculture-plant than in monoculture for both observation periods. This may be due to a broader range of food provided by polyculture patterns, hence more resources to support arthropods. These results were similar to [22], who found that a multi-cropping pattern had a positive influence on the diversity and evenness of arthropods. [23] showed that the variability of plants related to planting patterns could also affect the diversity arthropods such parasitoid.

3.3. Community resemblance

In the balangeran mixed with eucalyptus and balangeran monoculture, the arthropod community's similarity was higher than those of the balangeran, and paddy polyculture that observed two months after planting (Table 6). The communities of arthropod in the mixed with paddy and balangeran plants mixed with eucalyptus were more similar than the monoculture pattern of balangeran in the observations of three months after planting (Table 7). The low abundance and diversity of arthropod species in the ecosystem can cause low levels of community similarity between habitats [24].

Table 6. Species similarity matrix (Sorensen Index) of arthropods under monoculture and polyculture balangeran plants at two months after planting.

| Type of ecosystem | Balangeran + Paddy | Balangeran + Cajuput | Balangeran  |
|-------------------|---------------------|----------------------|------------|
| Balangeran + Paddy| 1.00                |                      |            |
| Balangeran + Cajuput| 0.60               | 1.00                 |            |
| Balangeran        | 0.73                | 0.44                 | 1.00       |
Table 7. Species similarity matrix (Sorensen Index) of arthropods under monoculture and polyculture balangeran plants at three months after planting.

| Type of ecosystem | Balangeran + Paddy | Balangeran + Cajuput | Balangeran |
|-------------------|--------------------|----------------------|------------|
| Balangeran + Paddy| 1.00               |                      |            |
| Balangeran + Cajuput| 0.93           | 1.00                 |            |
| Balangeran         | 0.71               | 0.53                 | 1.00       |

The natural ecosystem has higher diversity than the cultivation ecosystem. [22] reported that the diversity of arthropod on mixed cropping patterns was higher than on monoculture. Therefore, balangeran plants mixed with paddy and balangeran mixed with cajuput were more similar than on monoculture of balangeran.

4. Conclusion

Planting system and type of vegetation appeared to have affected the diversity and abundance of arthropods. The arthropods found in balangeran mixed with cajuput plants had the highest diversity and abundance compared to other planting systems. The observed arthropods were classified as predator, phytophag, parasitoid, and pollinator. The arthropods obtained were from 10 orders, and 24 families with the highest number of individuals belong to Formicidae, which were found in balangeran plants mixed with cajuput plants. The dominance index of arthropods on balangeran plants mixed with paddy crop was higher than other planting systems.

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References

[1] Martawijaya A and Kartasujana I 1977 Ciri Umum, Sifat dan Kegunaan Jenis-Jenis Kayu Indonesia (Bogor: Lembaga Penelitian Hasil Hutan)
[2] Suryanto, Hadi T S, and Savitri E 2012 Budidaya Shorea balangeran di Lahan Gambut. Kementerian Kehutanan (Banjarbaru: Balai Penelitian Kehutanan Banjarbaru)
[3] Atmoko T 2011 Potensi Regenerasi dan penyebaran Shorea balangeran (Korth.) Burck di sumber benih Saka Kajang, Kalimantan Tengah J. Penelit. Dipterocarpa 5 (2) 21-36
[4] Laganiere J, Pare D and Bradley R L 2009 Linking the abundance of aspen with soil faunal communities and rates of belowground processes within single stands of mixed aspen – black spruce Appl. Soil Ecol. 41 19-28
[5] Kwon T S, Park Y K, Lim J H, Ryou S H and Lee C M 2013 Change of arthropod abundance in burned forests: Different patterns according to functional guilds J. Asia. Pac. Entomol. 16 (3) 321-328
[6] Ebeling A, Hines J, Hertzorg L R, Lange M, Meyer S T and Simons N 2018 Plant diversity effects on arthropods and arthropod-dependent ecosystem functions in a biodiversity experiment Basic Appl. Ecol. 26 50-63
[7] Whitcomb W H 1974 Sampling Spiders in Soybean Fields (New York: Springer-Verlag)
[8] Niemela J, Halme E and Haila Y 1990 Balancing sampling effort in pitfall trapping of carabid beetles Entomol. 1 233-238
[9] Triplehorn C A and Jhsonson N F 2005 Borror And Delong's Introduction To The Study Of Insects (USA: Peter Marshall)
[10] Bolton B 1994 Identification Guide to the Ant Genera of the World (London: Harvard University Press)
[11] Maguran A E 1983 Ecological Diversity and Its Measurement (New Jersey: Princeton University Press)
[12] Ludwig J A and Reynolds JF 1988 Statistical Ecology: A Primer on Methods and Computing
[13] Pandeya S C, Puri G S and Singh J S 1968 Research Methods in Plant Ecology (London: Asia Publishing House)

[14] Putra I M, Hadi M and Rahadian R 2017 Struktur komunitas semut (Hymenoptera: Formicidae) di lahan pertanian organik dan anorganik Desa Batur, Kecamatan Getasan, Kabupaten Semarang *Bioma Berk. Ilm. Biol.* **19** (2)

[15] Wallwork J A 1970 Ecology of Soil Animals (London: McGraw-Hill)

[16] Ghazali A, Asmah S, Syafiq M, Yahya MS, Aziz N, Peng T, Norhisham A R, Puan C L, Turner E C and Azhar B 2016 Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity *J. Asia. Pac. Entomol.* **19** (2) 415-421

[17] Albers D, Migge S, Schaefer M and Scheu S 2004 Decomposition of beech leaves (Fagus sylvatica) and spruce needles (Picea abies) in pure and mixed stands of beech and spruce *Soil Biol. Biochem.* **36** 155-64

[18] Noordijk J, Schaffers A P, Heijerman T, Boer P, Gleichman M and Sýkora K V 2010 Effects of vegetation management by mowing on ground-dwelling arthropods *Ecol. Eng.* **36** (5) 740-750

[19] Lubis S R 2009 Keanekaragaman dan Pola Distribusi Tumbuhan Paku Di Hutan Wisata Alam Taman Eden Kabupaten Toba Samosir Provinsi Sumatera Utara (Medan: Universitas Sumatera Utara)

[20] Abdiyani S 2008 Keanekaragaman jenis tumbuhan bawah berkhasiat obat di dataran tinggi Dieng *J. Penelit. Hutan dan Konserv. Alam* **5** (1) 241–254

[21] Widiarta I N, Kusdiaman D and Suprihanto 2006 Keragaman arthropoda pada padi sawah dengan pengelolaan tanaman terpadu *J. HPT Trop.* **6** 61-9

[22] Pardon P, Reheul D, Mertens J, Reubens B, De Frenne P, De Smedt P, Proesmans W and Van Vooren L 2019 Gradients in abundance and diversity of ground-dwelling arthropods as a function of distance to tree rows in temperate arable agroforestry systems *Agric. Ecosyst. Environ.* **270-271** 114-128

[23] Utami S, Triwidodo H, Pudjiianto, Rauf A and Haneda N F 2018 Population dynamics of arthroschista hilaralis pest and its parasitoid diversity in various jabon (*Anthocephalus cadamba*) cropping patterns in south Sumatra, Indonesia *Biodiversitas* **19** (1) 239-245

[24] Herlinda S, Waluyo W, Estuningsih S P and Irsan C 2008 Perbandingan keanekaragaman spesies dan kelimpahan arthropoda predator penghuni tanah di sawah lebak yang diaplikasi dan tanpa aplikasi insektisida *J. Entomol. Indo.* **5** (2)