Indirect effect of pesticides utilization towards diversity of pollinator insects in chili plantation

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Abstract. The contribution of insect pollinators to the ecology and production of food crops is threatened by excessive use of pesticides. Pesticides have an impact on reducing the presence of pollinators in agricultural land. The diversity of pollinators depends on food availability and habitat quality. This research emphasizes the diversity of insect pollinators by the application of pesticides in chili plantations in Muaro Jambi, Sumatra. Insect observations were conducted on April-May 2018 using the scan sampling method. Specimen collection is carried out from 08.00-16.00. Data analysis used Shannon-wiener diversity index (H'), Simpson's index (D), and Pielou evenness index (E). The results of the study were 498 collected individuals consisting of 9 species. Apis melifera, Apis cerana, and Eurema hecabe are the most dominant insect pollinators. Whereas Apis mellifera showed two peaks of flower visitation (an intense first one between 08.00 until 11.00 a.m. and a second less intense one after 14.00 p.m.). Pollinator insect diversity index in the medium category. Our observations also show that the application of pesticides, anthesis and dehiscence to flowers as well as the activity of pollinating insects which together cause low diversity index values.

1. Introduction
Vegetable production, including chili, is one of the horticultural plants that has a very high market demand compared to cereals and staples from other plant sectors. In 2012, chili cultivation was more than 1,900,000 ha in the world with a production of 31,170,000 tons. The five highest chili producing countries are China, Mexico, Turkey, Indonesia and Spain. Efforts to meet market needs continue to be increased by increasing crop production. Increased crop production by farmers has continued in recent years as a result of environmental management, the development of superior varieties, the use of insecticides, and the use of chemical fertilizers on conventional agricultural land to accelerate the rate of crop production [1].

Management on conventional land as an intensification of agriculture will create its own challenges, namely as a controller of pests and diseases, but on the other hand the environment will face a serious threat [2] on environmental health and the loss of pollinators. On the other hand, pesticide input is needed in commercial crop production to suppress pest populations [3] to protect plants from pests and pathogens. Pesticides (herbicides, insecticides, and fungicides) are used to improve the quality of crop production. Many types of pesticides such as organopospat (OP), carbamate [4], neurotoxic insecticides, fungicides [5], pyrethroids [6] used in agricultural intensification are very dangerous to pollinators [4]. The level of pesticides that are considered safe by farmers significantly influences the survival of pollinators [7].
The pollination process directly or indirectly contributes more than 75% to the world's crop production and 87.5% of the pollination process is assisted by animals [8]. Honey bees (Apis melifera L.) are the most potential insects for pollinating plants that have generalist [9,10]. reported that increased crop production increased with the presence of wild bee visits. Kleijn et al., [11]; Winfree et al., [12] also proved that as a small species, bees are able to play an important role in helping plant production. Pollination of 90% of plants is also assisted by wild bees (Bombus spp), solitary bees, flies, and Lepidoptera [13,5]. The results of a study conducted by Azmi et al., [13] showed that chili pollinated with the help of a pollinator produced chilies with more seeds per fruit, heavier fruits, and more durable chili fruits, larger chili diameter, and size chili is longer than self-pollination or with human assistance.

Significant decreases in pollinator populations have been widely reported throughout the world and increasingly raise concerns about food security [14,15]. Among the many factors that affect bee populations and other pollinators are pesticides and loss of natural habitat [16]. Pilatic [17] states that since 2006 the insect population has decreased 26-36% annually due to the use of pesticides. The results of research conducted by Evans et al., [5] reported that agricultural systems that use pesticides (such as fungicides and insecticides) increasingly support the reduction of pollinating insects in the ecosystem. The results of laboratory experiments [17] neonicotinoid insecticides have a deadly effect on pollinators.

Farmers' ignorance of the importance of insect pollinators on agriculture as well as the impact of the use of unwise pesticides has a huge detrimental effect on pollinators. Azmi et al [13] explained that pollinators are very important in helping the process of fertilization of chili to increase the production of chili. The lack of pollinators results in a low supply of pollen distributed during fertilization.

Pesticide application is carried out by farmers at 07.00-10.00 in the morning with an interval of 5 days. This coincides with the time of pollinator activity in searching for nectar so that it gives a direct influence on its existence. This study aims to determine the abundance and richness of pollinator types in chili plantations in Muaro Jambi, Jambi Province, Sumatra.

2. Methods

2.1. Study area
This research was conducted at a chili plantation in Muaro Jambi Regency, Jambi Province which is geographically located at a coordinate point of 103631.66° S - 10303104.55° E with an altitude of 50 m above sea level in April - May 2018. This research area has an area of 1 Ha. We recorded the application time of fungicides and insecticides.

2.2. Collection and identification of pollinators
Pollinator observations are made using the scan sampling method. Insect observations were conducted on April 5-9 (5 days) (A), 17-21 (5 days) (B), April 29-May 3 (5 days) (C), May 11-15 (5 days) (D), and 23-27 (5 days) (E) 2018 respectively. Observations begin at 08.00 - 16.00 for 45 minutes / hour [18]. The pollinator collection was carried out by four people to explore the study area using insect nets and then stored in triangular paper envelopes. The identified pollinator is recorded directly in the field. Collected specimens were taken to the laboratory for identification at the Genus level with the aid of a stereo microscope. Pollinator insect identification based on Peggie and Amir for Lepidoptera and Nidup and Dorji for Bees.

2.3. Data analysis
The data obtained is tabulated into ms. excel for analysis. Diversity of butterflies were analyzed using the Shannone Wiener diversity index (H') (H' = -\sum_{i=1}^{R} P_i \ln P_i), Pielou evenness index (E) [18] dan Simpson's Index (D = 1/\sum_{i=1}^{R} P_i^2) [19]. Shannon-Weiner index combines evenness and richness into a single measure and assumes that all genera are represented in a sample while Simpson's index gives more weight to common genera and assumes that the few rare ones with only a few representatives will not affect the diversity values [19].
3. Results and discussion

3.1. Pollinating insect diversity

The results of this study found 498 pollinating insects consisting of 9 species from 2 orders (Lepidoptera and Hymenoptera, respectively 57% and 43%). Three species of pollinator insects that visited the flowers showed the highest abundance, namely Apis melifera (Hymenoptera) (27%), Apis cerana (Hymenoptera) (16%), Eurema hecabe (Lepidoptera) (14%). Both of these orders are the main pollinators of chili horticulture plants.

The diversity of pollinators in the observations are (A) shannon wiener index $H' = 2.0$, Pielou E similarity index $E = 0.96$, and simpson index $D = 0.15$; (B) shannon wiener index $H' = 1.9$, Pielou E similarity index $E = 0.91$, and simpson index $D = 0.17$; (C) shannon wiener index $H' = 2.1$, Pielou E similarity index $E = 0.95$, and simpson index $D = 0.14$; (D) shannon wiener index $H' = 1.8$, Pielou E similarity index $E = 0.95$, and simpson index $D = 0.18$; (E) shannon wiener index $H' = 1.9$, Pielou E similarity index $E = 0.88$, and simpson index $D = 0.17$. Overall, the Diversity Index value is in the moderate category because it is between $>1$ and $<3$.

Table 1. Number of species and individual insect pollinators in conventional chili plantations.

| Taxon          | Species            | Number of individual | Total | Percentage (%) |
|----------------|--------------------|----------------------|-------|----------------|
|                |                    | A       | B       | C       | D       | E       | Total | A | B | C | D | E | Total |
| Hymenoptera    | Apis cerana        | 15      | 18      | 12      | 18      | 15      | 78    | 17 | 15 | 11 | 21 | 15 | 16   |
| Hymenoptera    | Apis melifera      | 21      | 36      | 24      | 21      | 33      | 135   | 24 | 30 | 23 | 24 | 33 | 27   |
| Lepidoptera    | Eurema hecabe      | 12      | 18      | 15      | 15      | 12      | 72    | 14 | 15 | 14 | 17 | 12 | 14   |
| Lepidoptera    | Neptis leucoporus  | 9       | 6       | 12      | 9       | 6       | 42    | 10 | 5  | 11 | 10 | 6  | 9    |
| Lepidoptera    | Acrae violae       | 6       | 12      | 12      | 6       | 45      | 54    | 10 | 10 | 9  | 14 | 6  | 9    |
| Lepidoptera    | Cupha ermyanthis   | 6       | 3       | 6       | -       | 3       | 18    | 7  | 3  | 6  | 0  | 3  | 4    |
| Lepidoptera    | Junonia orithya    | 9       | 15      | 12      | 6       | 12      | 54    | 10 | 13 | 11 | 7  | 12 | 11   |
| Lepidoptera    | Hypolimnas bolina  | -       | 3       | -       | 3       | 6       | 9     | 0  | 0  | 3  | 0  | 3  | 1    |
| Lepidoptera    | Mycalesis perseus  | 9       | 12      | 12      | 6       | 9       | 48    | 10 | 10 | 11 | 7  | 9  | 10   |
| Number of individuals | 87 | 120 | 105 | 87 | 99 | 498 | 100 | 100 | 100 | 100 | 100 | 100 |
| Shannon Wiener diversity index ($H'$) | 2.0 | 1.9 | 2.1 | 1.8 | 1.9 | 2.1 |
| Simpson’s Index ($D$) | 0.15 | 0.17 | 0.14 | 0.18 | 0.17 | 0.15 |
| Pielou evenness index ($E$) | 0.96 | 0.91 | 0.95 | 0.95 | 0.88 | 0.96 |

3.2. Morphology of chilies flower

Blossoms resemble Solanaceae flowers in general which have a white corolla with 5-7 stamens containing 1-1.5 mg of pollen, have stems setigma above. Anthesis and dehiscence in chilli flowers occur in the morning between 7 and 9 am [5]. Anthesis and dehiscence time variations are caused by environmental temperature and humidity and genotype factors [20].

Figure 1. Pollination of chili flowers by bees.
3.3. Diversity and level of pollinator visits to chili plantation flowers

We note that the diversity index in this study is in the moderate category. We suspect that the application time of insecticides and fungicides at 07.00-10.00 which coincides with the time of anthesis and dehiscence as well as pollinator activity in finding nectar and pollen in chilli flowers is the cause of the diversity index in the medium category. The group fungiocarbamate with mankozeb active ingredient and Abamectin active ingredient used by farmers has an indirect impact on the presence of pollinators.

The results of research conducted by Kinasih et al., [21] mankozeb active substances have a moderate level of toxicity based on LD50 test and cause death at the individual level as well as on colonies against bees. Copy it, the results of Aljedani's study [22] of the type of insecticide active ingredient abamectin caused 90% death of worker bees with digestive system damage.

![Figure 2](image_url)

**Figure 2.** Number of individual pollinators collected on chili plantations at different times (8:00 a.m. - 4:00 p.m.) in April-May.

The results of this study also showed that the level of pollinator visits varied based on the time of observation (Figure 2). The visit of the highest pollinator at 08.00-09.45 and continued to decline sharply at 10:00 to 12:00. Pollinator visits to chilli flowers were not found at 12.45-14.00. At 14.30-15.45 we noted that only *Apis mellifera* was found with the number of individuals increasing late in the afternoon in the observation groups C, D, and E. Tschoeke et al., [23] mentioned the pollinator's visit to flowers was influenced by the time and temperature of the environment. The highest intensity of pollinator visits is between 8:00 and 11:00 in the morning and decreases around 12:00 noon. *Apis mellifera* L. species were also documented found in the afternoon 16.00. The activity of pollinators in finding the highest nectar and pollen in the morning. The decrease in pollinator visits to flowers during the day is due to evaporation and decreased nectar production due to an increase in environmental temperature [24].

The results of other studies also showed that bees that eat pollen and nectar contaminated with neonicotinoids (insecticides) can affect the physiology and behavior of bees, reproduce by producing small offspring, decreased sperm viability, ovarian disorders in the queen bee [25] Damage to bee colonies depends not only on chemical toxicity, but the method and timing of pesticide application along with the anthesis and dehiscence process causes contamination of pollen and nectar consumed by bees. Insecticides and fungicides (pyrethroids) applied together can increase toxicity 100 times to kill honey bees [6].

Species richness in pollinators is lower on agricultural land which is applied by pesticides. However, only a few species have high abundance [4]. Low ecosystem stability can cause changes in the composition of its constituents which have an impact on biodiversity decline.
4. Conclusion
This study provides insights to farmers about the importance of using pollinating insects in the horticultural farming system widely, especially on chili plantations. Chemical management and input in conventional plantations must be a concern for the sustainability of the ecosystem cycle.

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