The effect of pollinator insect visitation on flower development and productivity of chilli plant

T Aminatun¹, Budiwati¹, I Sugiyarto¹, S A Setyawan² A Desiliani²

¹Biology Department, Faculty of Mathematics and Science, Universitas Negeri Yogyakarta
²Students of Biology Department, Faculty of Mathematics and Science, Universitas Negeri Yogyakarta
*e-mail: tien_aminatun@uny.ac.id

Abstract. This research aimed to find out; (1) the pollinator insect diversity of chili plant; and (2) the effect of pollinator insect visitation on flower development and productivity of chili plant. This experimental study was designed with a factorial completely randomized design. The independent variable was visitation of pollinator insect on plant, while the dependent variables were pollinator insect diversity, flower development, and productivity of chili plant. Each treatment consisted of 5 replicating plots, and each plot contained 4 potted plants. Flower development observation was carried out as long as the chili plant flowering. As supporting data were the frequency and longevity of pollinator visiting. The results showed pollinator insects on chili plants were Trigona, Apis, Lasioglossum, and Camponotus. The highest frequency of visitation were Trigona and Camponotus, while the highest longevity was Camponotus. The inhibitory treatment of pollinator insect visitation caused the plant began to flower more slowly and the flower bloomed last longer. The plant was also harvested 2 months slower, and the average number and weight of fruit per plant tended to be lower.

Keywords: visitation, pollinator, chili productivity

1. Introduction

Nearly 90% of flowering plants depend on pollinators for the process of sexual pollination or reproduction, especially the types of agricultural crops [1]. Many insect species act as pollinators for agricultural crops. Pollination by insect pollinators can be categorized as an ecosystem service that is beneficial for humans.

Many agricultural commodities have flowers that are hermaphrodite with anthers that form cones, so that the release of pollen from the pistil head requires vibration. Although these plants can self-pollinate, cross-pollination with the help of insects is needed to improve the quality and quantity of fruit [2]. An example of this type of plant is chili. Chili is an agricultural commodity that is quite important in Indonesia and of high economic value. Therefore, the existence of barriers to the activity of insect pollinators on the flowers of chili plants can affect the quality of the fruit, which means that it will affect the productivity of agricultural products from the chili plants.
Order of Hymenoptera or class of wasps and bees are the main pollinator insects on agricultural crops, and have been widely used and developed in various countries. Some of the important families of this order are Apidae, Halictidae, Vespidae, and Megachilidae [1,3]. Organic farms showed that the insects that most often visited the flowers of tomato plants which are a family with chili plants, were from the order Hymenoptera, then followed by Diptera, Lepidoptera, Thysanoptera, Hemiptera and Homoptera [4]. The results of the study by [5] also showed that pollinator insects from the order Hymenoptera (Xylocopa virginica, Colletidae, Megachilidae, and Apidae) visited the flowers of tomato plants more than the Diptera order (Drosophila). According to [6] one member of the Apidae family is a local honey bee (Apis cerana javana) which spreads in almost all regions of Indonesia. This honey bee has been proven to be able to increase the production and quality of strawberry fruit. Furthermore, [1] also explained that bee Xylocopa has the advantage of being an insect pollinator, because it has a large body size, is able to fly fast and far in conditions of rapid wind, is able to suppress closed petals, is able to take sticky leaves by vibrating flower or commonly called buzzing, and is able to visit various types of flowers, especially if the interest is not his favorite.

Based on the background, it is necessary to do research on whether the types of pollinator insects that visit the flowers of chilli plants are the same as pollinator insects that visit other plants that are of the same family, such as tomato plants. In addition, it is necessary to know the effect of the inhibition of pollinator insect visitation on the flowers of chilli plants on the productivity of these agricultural crops. Productivity can be seen from the amount and weight of fruit produced per plant. Therefore, the purpose of this study is to find out; (1) any insect that acts as a pollinator for chili plants; (2) the influence of pollinator insect visitation on the development of chili plant flowers as an agricultural plant; and (3) the influence of pollinator insect visitation on the productivity of chili plants seen from the number and weight of fruit per plant.

2. Method
This research is an experimental study with a factorial 1 complete randomized design, namely the treatment of visitation and inhibition treatment of pollinator insects on chili plants, each of which consists of 5 replicating plots, and each plot contains 4 plant pots. The distance between the pots is 20 cm, while the distance between the plots is 1 meter. The research was conducted in the FMIPA UNY experimental garden. The independent variable is visitation inhibition of pollinator insects on plants. The dependent variable is the development of interest (amount and age of interest per plant), and productivity seen from the number and weight of fruit per plant. The intermediate variables in this study are the frequency and longevity of the visit of the pollinator.

The material used is paranet to inhibit visitation of pollinator insects, pots for planting chili plants, chili seeds, soil media, compost fertilizer, and materials for the nurture of chili plants. The equipment needed for data retrieval is a camera and video camera, stationery, calipers, scales, and equipment for measuring microclimates (thermometer, luxmeter, hygrometer, and anemometer).

Seeding is carried out by spreading chili seeds on the tray, then after growing to reach 3 leaves, the plants are transferred to the pot and placed in the research plot. Each pot contains 1 plant, and each plot contains 4 plant pots. The chili planted was ORI 212. Plots were placed randomly between treatments. Inhibition of pollinator visitation is done by covering the treatment plot with paranet with a density level of 60% so that it does not allow insect pollinators to approach the plants. Installation of paranet in the treatment is at the 5th week after planting, which is when the plants approach the flowering phase.

Plant maintenance is carried out in common ways which include watering plants, fertilizing and weeding. Watering is done every day, fertilization is done every 2 weeks using SNN liquid organic fertilizer (Super Natural Nutrition) with the amount of 4L with a concentration of 33 cc / L, and pest control is done every 2 weeks by spraying vegetable pesticides with Metani brand with concentrations of 100gr / 10L or 10gr / L.

Measurement of microclimatic factors is carried out every week of observation (2 weeks), intended to control the optimum environmental conditions for the growth of chili plants. Observation
of pollinator insect was carried out on treatment plots where there was no inhibition when the plants had flowered. This observation included types of insect pollinators visited the flowers, their frequency, and their longevity. The observations were carried out at 8-11 am on each plant in each observation plot. The used method in observing insects is scan sampling [7]. Insects, which are not yet known at the time of observation, are captured by sweep net for identification purposes. Observation of the number of flowers per plant and age of flowers is carried out as long as the chili plants flower. Retrieval of plant productivity data were carried out at harvest which includes the number of fruits and the weight of fruit per plant.

The data obtained were then analyzed using descriptive quantitative method to see the effect of visitation treatment and inhibition treatment of pollinator insect visitation on the productivity of chili plants seen from the average number and weight of fruit per plant.

3. Results and Discussion

3.1 Polinator Insect on Chili Flower

The types of pollinators found in the flowers of chili plants are presented in Table 1. Based on Table 1 it is known that there are 2 groups of pollinator insects, namely groups of bees (family Apidae and Halictidae) and groups of ants (familia Formicidae), both are included orders of Hymenoptera, while spiders are predatory arthropods (not insects) that perch on flowers and can also help pollinate flowers.

| No | Order   | Family | Genus   | Local Name |
|----|---------|--------|---------|------------|
| 1  | Hymenoptera | Apidae | Trigona | Honey Bee  |
| 2  | Hymenoptera | Apidae | Apis    | Bee        |
| 3  | Hymenoptera | Halictidae | Lasioglossum | Bee |
| 4  | Hymenoptera | Formicidae | Camponotus | Ant |
| 5  | Aracneae | Oxyotidae | Oxyopes | Spider |

Of the two groups of insect pollinators in Table 1, the highest longevity visitation was the ant group (Table 2).

| NO | Order   | Family | Genus   | Frequency (times) | Longevity Average (seconds) |
|----|---------|--------|---------|------------------|-----------------------------|
|    |         |        |         | Period I | Period II | Period I | Period II |
| 1  | Hymenoptera | Apidae | Trigona | 18        | 36       | 18.4     | 14.3      |
| 2  | Hymenoptera | Apidae | Apis    | 0         | 2        | 0        | 9.5       |
| 3  | Hymenoptera | Halictidae | Lasioglossum | 0 | 2        | 0        | 21.5      |
| 4  | Hymenoptera | Formicidae | Camponotus | 22 | 7        | 35.0     | 27.7      |
| 5  | Aracneae | Oxyotidae | Oxyopes | 1         | 0        | 46       | 0         |

Observations of pollinator visitations were carried out in 2 periods, with a distance between periods of 1 month. The first period is when chili plants flower first, while period II is the next
flowering season (Table 3). At the beginning of flowering, the number of flowers is not as much as in period II, so there are not many insect pollinators. At the beginning of flowering there are only 3 types of pollinators visiting chili plants, while in the next flowering season there are 5 types of insect pollinators. The type of Camponotus (ant) is the one having the highest longevity in both period I and II, while the frequency of most visitations in period I is Camponotus and in period II is Trigona bee.

### Table 3. Number ofBlooming Flowers in 3 Days of Observation in Period I and II

|                    | Period I |          |          | Period II |          |
|--------------------|----------|----------|----------|-----------|----------|
|                    | Day I    | Day II   | Day III  | Day I     | Day II   | Day III  |
| Number of Blooming |          |          |          |           |          |          |
| Flowers            | 6        | 11       | 17       | 47        | 9        | 4        |

Based on Table 3, it can be seen that in the first blooming phase, there are many flowers that have not bloomed. Then the number increased to reach the highest peak in period II on the first day of observation, whereas in day II and III the number decreased sharply because the many flowers begin to wilt after experiencing pollination.

The flowers of chili plants (Capsicum annuum), like most plants of the Solanaceae family, hang on the base of white leaves having 5-7 stamens [8]. The anthers are tubular and can be seen when exposed. According to [9] although chili flowers produce nectar and pollen, they do not attract pollinator insects because chili plants are self-pollinating plants. However, data in the field shows that cross-pollination of these plants ranges from 7% - 91%, so that this plant is considered as a self-pollinating.

Cross pollination that occurs can take place with the help of insect pollinators. On the slopes of Mount Slamet, the flowers of chili plants are visited by 9 species of insect pollinators. This is in line with the results which show that chili flowers were visited by 16 species of wild bees including Hylaeus sp. and Bombus sp. These results indicate that although theoretically chili flowers do not attract insect pollinators but in fact many pollinator insects visit chili plant flowers [10].

Pollinator insects play an important role in natural ecosystems, especially in helping wild plants to do pollination. Maintaining the diversity of pollinator insect communities is the right way to overcome the shortcomings of pollinator insects in nature because each species of insect pollinator has a different way of life and environmental sensitivity so that it will provide great space and time stability and be able to maintain the sustainability of ecosystem functions in nature [8,11].

### 3.2. The Effect of Pollinator Insect Visitation on Chili Flowers

7 weeks after planting, chili plants given the visitation treatment had begun to flower while those given the other treatment had not. Chili plants given the inhibition treatment of pollinator insect visitation started to flower at the age of 11 weeks after planting. This is due to the ORI 212 variety requires higher light intensity for the flowering process, while the paranet treatment lower the light intensity (Table 4).

The study conducted [8] on 3 chili varieties (Bhaskara, F1 Pelita, and Dewata 43F1) showed that paranet shade significantly affect flowering age and response to paranet shade is strongly influenced by plant varieties. Dewata 43F1 produces flowers faster than Bhaskara and Pelita F1. Baskara variety is the slowest to produce flowers. The 60% of shade treatment causes plants to flower faster than those given the 40% of shade treatment. Therefore, in all three varieties, low light intensity does not inhibit the process of flower formation.
Table 4. Light Intensity in Paranet Shade Treatment (the Inhibition Treatment of Pollinator Insect Visitation) and without Paranet Shade Treatment (without the Insect Polynatorial Visitation Treatment)

| Light Intensity (Lux) | Period I | Period II |
|-----------------------|----------|----------|
| Without Paranet Treatment (without inhibition of pollinator insect visitation) | 6,348 | 22,719 |
| With Paranet Treatment (with Inhibition Treatment of Pollinator Insect Visitation) | 1,721.2 | 5,457 |

The inhibition treatment of pollinator insect visitation prolongs the life cycle of chili plants while the other treatment does not. The observation shows that chili flowers in the Insect pollinator visitation treatment (without inhabitation) bloom for one day only and on the second day the flowers had begun to wither. Meanwhile, chili flowers in the other treatment bloomed for 2 days and began to wither on the 3rd day.

3.3. The Effect of Pollinator Insect Visitation on Chili Plant’s Productivity

During the early stage of this research, there is a pest attack when the plants start to produce fruits. The pest is Bactrocera dorsalis fruit fly, and as a result the chilli plants can be harvested in the 11th week after planting.

The inhabitation treatment also influences the time the plants produce fruits and fruit’s weight per plant. Plants without the inhabitation treatment flower and bear fruits faster than plants with the inhabitation treatment.

The plants with inhibitory treatment of pollinator insect visitation took more time to produce fruits that they were only harvested for the first time when the plants without inhibitory treatment had been harvested for the third period. The quality of fruit, indicated by the weight, was also better in the plants without inhibitory treatment. The productivity data can be seen in Table 5.

Table 5. The average number and weight of fruit per plant in plants with inhibitory treatment and those without inhibitory treatment in two harvest periods

| Harvest period | The average number of fruit per plant | The average weight of fruit per plant (gr) |
|----------------|---------------------------------------|--------------------------------------|
|                | With pollinator inhibitory treatment | Without pollinator inhibitory treatment | With pollinator inhibitory treatment | Without pollinator inhibitory treatment |
| I              | 3                                     | 2                                    | 2.5                                  | 2.4                                   |
| II             | 5                                     | 19                                   | 4.6                                  | 26.5                                  |

Based on Table 5, the number and weight of fruit per plant in the inhibitory treatment of pollinator insects also tend to be less and lower. The second harvest period increased from the first harvest period, both in the average number and the average weight of the chili fruit per plant. This increase was much sharper in the plants without inhibitory treatment of pollinator insects. Based on the result of ANOVA test, the difference of the average number and weight of fruits between with
inhibitory and without inhibitory treatments are significantly different, with sig < 0.05. This is consistent with the statement of de [12] on how the presence of pollinator insects will improve fruit quality and reduce the failure of fruit formation. [6] who examined the effect of the abundant honey bees (Apis cerana and Trigona laeviceps) on the increasing production of strawberries, also found that the increase in the abundance of both types of bees could increase the production and quality of strawberries.

4. Conclusions
The conclusions of this research are as follows. (1) The pollinator insects on the chili flower plants consist of two groups, namely the group of bees (Trigona, Apis, and Lasioglossum) and the ant group (Camponotus), both included in the Hymenoptera order, with the highest frequency of visitation by Trigona and Camponotus, and the highest longevity by Camponotus. (2) The inhibitory treatment of pollinator insect visitation affects the speed of plants to flower and the age of the flower, as the plants begin to flower more slowly, and the age of the blooming flower becomes longer. Finally, (3) the inhibitory treatment of pollinator insect visitation negatively affects the speed of the plants to produce fruit, as well as the average number and weight of fruit per plant.

5. Acknowledgments
The authors thank the Institute of Research and Community Service of Universitas Negeri Yogyakarta for the funding of this research in 2018.

References
[1] Widhiono I 2015 Strategi konservasi serangga pollinator Univ. jenderal Soedirman, Purwokerto 86
[2] Greenleaf S S and Kremen C 2006 Wild bee species increase tomato production and respond differently to surrounding land use in Northern California Biol. Conserv. 133 81–7
[3] Bugnon J-L, Rochefort L and Price J S 1997 Field experiment of Sphagnum reintroduction on a dry abandoned peatland in eastern Canada Wetlands 17 513–7
[4] Fajarwati M R, Atmowidi T and Dorly D 2016 Keanekaragaman Serangga pada Bunga Tomat (Lycopersicon esculentum Mill.) di Lahan Pertanian Organik J. Entomol. Indones. 6 77
[5] Aminatun T and Putra N S 2017 The effect of habitat modification on plant-pollinator network AIP Conference Proceedings vol 1868(AIP Publishing)p 90004
[6] Mz I W, Sudiana E and Sucianto T 2012 Potensi Lebah Lokal Dalam Peningkatan Produksi Buah Strawberry(Fragaria X Ananassa) 6 163–8
[7] Sceisarriya V M Problematika Pelaksanaan Pendidikan Jasmani di Sekolah Dasar Pros. Semin. Nas. Prof. Tenaga Profesi PJK 153–9
[8] Winfree R, Williams N M, Gaines H, Ascher J S and Kremen C 2008 Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA J. Appl. Ecol. 45 793–802
[9] Delaplane K S, Mayer D R and Mayer D F 2000 Crop pollination by bees (Cabi)
[10] Raw A 2000 Foraging behaviour of wild bees at hot pepper flowers (Capsicum annuum) and its possible influence on cross pollination Ann. Bot. 85 487–92
[11] Garibaldi L A, Steffan-Dewenter I, Kremen C, Morales J M, Bommarco R, Cunningham S A, Carvalheiro L G, Chacoff N P, Dudenhöffer J H and Greenleaf S S 2011 Stability of pollination services decreases with isolation from natural areas despite honey bee visits Ecol. Lett. 14 1062–72
[12] Cruz C D, Neto F L, Castro-Lopes J, McMahon S B and Cruz F 2005 Inhibition of ERK phosphorylation decreases nociceptive behaviour in monoarthritic rats Pain 116 411–9