Pollinator diversity and soybean productivity with flowering plant (Crotalaria and Rosella)

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Abstract. Soybean is an important food crop in Indonesia with low productivity. Soybean production could be increased by increasing ecological services functions such as pollinator. The purpose of this study was to determine the effect of flowering plant (crotalaria and rosella) to the diversity of pollinators and their ability to enhance soybean productivity. The treatments consisted of control treatment soybean monoculture (P0), soybeans with rosella (P1), soybean with crotalaria and rosella (P2), and soybeans with crotalaria (P3). The research variables are the species and abundance of insects, insect activities, and soybean yield. The visitor flower insects consisted of Coleoptera (Coccinellidae); Hymenoptera (Apidae, Vespidae, Chalcididae, Sphecidae, Halictidae); Lepidoptera (Lycaenidae, Nymphalidae, Sesiidae) was dominated by Hymenoptera. Visitors flower insects of the soybean flower was from the family Apidae, there were Apis melifera, Xylocopa confusa, Trigona sp. The highest visiting frequency of insects in the soybean plot were in plot K3 (soybean, crotalaria and rosella). The visitors flower insects preferred the crotalaria than the rosella. Visitors flower insects which visit the crotalaria as Apis mellifera. Uncover of soybean flower could increase soybean pods. Treatment with cover got shaded and made soybean not optimal in forming pods.

1. Introduction
Soybean (Glycine max) is a food crop which is widely consumed by Indonesian people after rice and corn. Low soybean production has not been able to meet the increasing needs of society. Indonesian soybean production in year 2016 was 887.54 thousand tons and did not satisfy the needs of 1.60 million tons soybean production in Indonesia due to many factors. Optimum soybean growth is at daylight 14-16 hours; while Indonesia it is generally only 12 hours a day. Another reason was there were less pollinators in the planting area. Insects that are free to interact with plants can improve yields. There was an increase in yield of 6.34% from field that allowed free flowers to be visited by pollinating insects [1]. Soybean plants which pollination was assisted by honey bees can obtain pod production and seeds which increase respectively 61.38% for pods and 58.86% for seeds [2]. The increasing abundance and diversity of plants in a plot including habitat enrichment, because it can meet the needs of pollinating insects in all seasons. Provision of food sources through planting flowering plants is intended to increase the diversity of pollinators [3]. The numbers and variation of pollinators will help to increase the success of pod formation. Based on the problem of at least insects that interact with soybean flowers the idea arose to conduct research on increasing the diversity of pollinators so that soybean yields also increased and carried out by planting flowering plants as hoses.
2. Methods

This research was carried out in August 2017 to December 2017 with a field experiment consisting of 4 treatments namely control plots only planted with soybeans (P0); plot one planted with soybeans and rosella flowers (P1); plot 2 soybeans, rosella and crotalaria (P3); plot 3 planted with soybeans and crotalaria (P4). Sampling of soybean plants was carried out systematically with an X pattern of 10 samples, while for flowering plants was done randomly with 20 plant samples from each treatment plot. The observation method used is direct observation method by scan sampling. According to [4] which conducted a study of insect abundance by counting the number of species and individual visitor insects. Insect activity by capturing insects that land on flowers uses sweep net from tile material then insects are separated [5]. The variables observed were the activity and number of pollinators who visited the flower, the abundance of insect pollinators, the percentage of success in the formation of pods with the treatment of hoods and not hoods.

3. Results and discussion

3.1. Abundance of flower visitors' insects

The types of insect flowers visitors found on soybean fields with the planting of ornate and rosella flowers consisted of orders of Hymenoptera (Apidae, Vespidae, Chalcididae, Sphecidae, Halictidae), Lepidoptera (Lycaenidae, Nymphalidae, Sesiidae), and Coleoptera (Coccinellidae). Family Coccinellidae visit P1 and P2 plots with a total of 7 insect. The most dominant order of Hymenoptera is the Apidae family, Amegilla cingulata as many as 10 in the P2 plot. Melittia sp. is the Lepidoptera order that visited the most, 13 birds (Table 1). Insects of flower visitors will visit flowers to get nectar. Apidae insects will have an interest in nectar because it functions as an energy source. According to Brown et al. 2002 pollinating insects visit different flowers and shapes. Different types of insects in visiting flowers can be influenced by the type, color and shape of the flower. The diversity of pollinator insects is influenced by the diversity of flowering plants in the planting area [6]. Lepidoptera is commonly known as butterfly and moth. Many Lepidoptera insects have a closed body and limbs with a sucking mouth [7].

| Order       | Family                  | Visitor insects      | Treatments | Count | % | Count | % | Count | % | Count | % |
|-------------|-------------------------|----------------------|------------|-------|----|-------|----|-------|----|-------|----|
| Coleoptera  | Coccinellidae           | Coccinela sp.        | P0         | 6     | 24 | 7     | 28| 28    | 7  | 28    | 7  |
| Hymenoptera | Apidae                  | Amegilla cingulata   | P1         | 6     | 19 | 10    | 32| 7     | 23| 8     | 26 |
|             | Apis mellifica          | Xylocopa laticeps    | P2         | 3     | 43 | 4     | 57| -     | -  | -     | -  |
|             |                         | Xylocopa confise     | P3         | 3     | 15 | 5     | 25| 7     | 35| 5     | 25 |
|             | Vespidae               | Trigona sp           | P1         | 8     | 40 | 3     | 15| 7     | 35| 2     | 10 |
|             | Ropalidia fasciata     | Delta commaniforine  | P2         | 4     | 17 | 5     | 22| 9     | 39| 5     | 22 |
|             | Polistes sp            | Polistes sp          | P3         | 4     | 20 | 4     | 20| 7     | 35| 5     | 25 |
|             | Chalcididae            | Tyfonia sp           | P0         | 3     | 33 | 6     | 67| -     | -  | -     | -  |
|             | Sphecidae              | Sphex nudus          | P1         | 5     | 21 | 6     | 25| 6     | 25| 7     | 29 |
|             | Sceilprona caementarius|                     | P2         | 8     | 100| -     | - | -     | -  | -     | -  |
| Lepidoptera | Halictidae             | Angochora parvula    | P3         | -     | -  | 10    | 42| 8     | 33| 6     | 25 |
|             | Lycaenidae             | Strymon melina       | P0         | -     | 6  | 21    | 8 | 29    | 7 | 25    | 7  |
|             |                        | Junonia almana       | P1         | 8     | 23 | 11    | 31| 9     | 26| 7     | 20 |
|             |                        | Melittia sp          | P2         | 13    | 33 | 10    | 26| 8     | 21| 8     | 21 |

| TOTAL       |                        |                      | P0         | 85    | 23 | 105   | 28| 106   | 28| 81    | 21 |

P0 = Soybean monoculture; P1 = rosella and soybean; P2 = rosella, crotalaria and soybean; P3 = Soybean and Crotalaria
Flower insects that visit the most rosette flowers of the Coleoptera order are Coccinella sp. 5 insect. The Hymenoptera order that visited the most rosette flower was Xylocopa confusa 10. The most abundant order of Lepidoptera is Junonia almana as many as 11. The snord flowers were visited by Coleoptera orders as many as 14, while the Hymenoptera order was Trigon a sp. as many as 17 insects. The Lepidoptera order that visited the snore-flowered one was Junonia almana as many as 19 insects (Table 2).

### Table 2. Types and Population of insect visitor rosella and crotalaria flower

| Order    | Family      | Visitor insects                  | P0 | P1 | P2 | P3 |
|----------|-------------|----------------------------------|----|----|----|----|
| Coleoptera | Coccinellidae | Coccinella sp.                  | 3  | 8  | 12 | 35 |
| Hymenoptera | Apidae      | Amegilla cingulate               | 10 | 23 | 11 | 25 |
|          |             | Apis melifera                    | 0  | 0  | 11 | 50 |
|          |             | Xylocopa laticeps                | 0  | 0  | 10 | 45 |
|          |             | Xylocopa confusa                 | 7  | 16 | 17 | 40 |
|          |             | Trigona sp.                      | 10 | 19 | 16 | 30 |
|          |             | Ropalidia fasciata               | 10 | 23 | 13 | 30 |
|          |             | Delta commanforis                | 11 | 22 | 14 | 29 |
|          |             | Polistes sp.                     | 12 | 25 | 13 | 37 |
|          | Chalcididae | -                                | 10 | 20 | 11 | 22 |
|          | Sphecidiae  | Sphep nexus                      | 7  | 14 | 12 | 24 |
|          |             | Scelipron                        | 1  | 2  | 2  | 4  |
| Lepidoptera | Halictidae | Augochlora pura                  | 8  | 17 | 16 | 33 |
|          | Lycaenidae  | -                                | 9  | 20 | 16 | 36 |
|          | Nymphalidae | Junonia almana                   | 6  | 12 | 13 | 27 |
|          | Sesiidiae   | Melittia sp.                     | 13 | 28 | 15 | 33 |
|          |             | TOTAL                            | 132| 18 | 222| 30 |

P0 = Soybean monoculture; P1 = rosella and soybean; P2 = rosetta, crotalaria and soybean; P3 = Soybean and Crotalaria

The flower is snored in yellow and the size of the flower is bigger than the flower of soy and rosella. Xylocopa confusa is the most common insect visiting the soybean patch with rosella flowers and snoring. Xylocopa will pollinate more flowers that have a striking color with large flower sizes [8]. The abundance of insect visitors will be proportional to the amount of interest in the crop and will affect the abundance of insects [9]. Many factors influence insects to choose to visit certain flowers. The morphology of flowers and physical factors of a habitat can affect the abundance of flower visitors [6]. If the competition between insects is also the reason for the lack of insects visiting flowers [10]. Rosella flowers have anthocyanin content which can be found on the flower petals which will be stable if anthocyanins are at 25°C [11]. The flowers pollinated by honey bees will be different in results by polluting large wasps because of honey bees likes UV color patterns while wasps like red.

Bees have an interest in flowers that are influenced by the color of the flower and the distance of the flower [12]. Flower visitor insects are attracted to flowers because of the smell and chemicals present in flowers [13]. The more diverse the flowers there are, the number of insects will increase. The diversity of flower visitors is influenced by the density of flowers and the diversity of flowers [14]. Plants are able to produce different number of flowers; and this can affect the diversity of visiting insects [15]. The plot index value P0 shows the value of diversity 2.60 and diversity value 0.96. The treatment plot that has the highest diversity value is plot P2 in the snore plant which is 2.82 with a diversity value of 1. P2 plot of soybean plants has the highest diversity value among the values of the diversity of other plot soybean plants. The diversity value is 1 while the diversity value is 2.63. The lowest diversity value of P3 plot in soybean plants was 2.41 with a diversity value of 0.91 (Table 3).
Table 3. Variability index dan uniformity index of insect visiting flower of rosella soybean and crotalaria

| Index       | P0   | P1   | P2   | P3   |
|-------------|------|------|------|------|
| Variability | 2.60 | 2.71 | 2.66 | 2.69 |
| Uniformity  | 0.96 | 0.98 | 0.98 | 1.00 |

P0 = Soybean monoculture; P1 = rosella and soybean; P2 = rosella, crotalaria and soybean; P3 = Soybean and Crotalaria; K = Soybean, R = Rosella, O = Crotalaria

Insects that visit the soybean flowers in the control plot there are 15 types while the types of visitors for the soybean flower plot are the least observations, namely the P3 plot, which is 14 species. Insects who visit the Roselle flower as many as 15 types in the P1 and P2 plots. The most types of insects visit the snore flower, which is 17 species (Appendix 2-8) The insect diversity index is generally measured using the Shannon-Wiener diversity index which has the principle of H ≤ 1.0 (low diversity); 1.0 <H ≤ 3.0 (medium); H > 3.0 (height). The results of the observation plot diversity index are medium. Even higher values of evenness will show that the type of insect spreads and none is dominant. Flowering plants that are planted are capable to provide nectar and increase the diversity of insect flower visitors. The factors that influence insect visitation are nectar content, chemical compound content, sugar concentration and flower abundance.

3.2. Daily activities and number of pollinators visiting flowers

The results of the daily activity of the visitors of interest shows the difference in the time of their visit. In the morning the insects visit less and increase at 08.00 compared to daytime. The highest number of visitors to flower insects occurs at 07.00-09.00. Insects visited ornate flower the most (484 insects), while the number of insects visiting the rosella flower is 478 insect and 433 insect of soybean flowers. The number of insect visitors will decrease during the day and evening. The flowers that were most visited by insects during the day were 417 tailed snakes, while 411 rosell flowers and 388 smallest ones were soybeans. In the afternoon the insect population of flower visitors is decreasing. The snore-flowered flower is the most visited, which is 337 heads, 211 rosella flowers and 299 soy flowers. Insect activity that decreases in the afternoon is influenced by environmental factors such as temperature, humidity and wind speed.

The results obtained during observations indicate that insects active at 7:00 a.m. to 9:00 a.m., will decrease during the day and evening [16] say that the abundance of pollinating insects is influenced by factors of light intensity, temperature, air humidity and other factors. When the flower blooms, the availability of nectar and pollen increases. The diversity of insect flowers visitors is influenced by environmental factors, time, shape, color of flowers, number of blooming flowers, and the volume of flower nectar [17]. Insects which include Apidae familly are Amegilla cingulata, Apis melifera, Xylocopoda laticeps, Trigona sp., Xylocopa confusa. Trigona is one type of insect that actively visits flowers in the morning and afternoon but decreases in the afternoon. Number of Trigona sp. who visited the snore in the morning of 36 insect. Trigona sp. also active during the day with the most visited number of snakes 34 heads. The number of these insects will decrease in the afternoon. [18] said that Trigona sp. will conduct foraging activities in the morning until evening according to the volume of nectar that will decrease in the afternoon. The most time of Trigona's visit occurred at 09.00-13.00 [19].

3.3. Soybean production

Insect visitors take nectar flowers and can function to help pollinate the flowers. The presence of pollinating insects can help increase production. Insects role in increasing fruit yields and seeds are influenced by size, morphology and feed search activities on plants [20]. Soybean yield which is a component of observation is the number of pods, the number of flowers formed, and the number of pods filled. The results of pods formed a plot of P0 with the highest cover treatment 146 pods, flowers formed 168 flowers and pods containing 49 pods. The lowest yield on the P3 plot is 81 pods, the flowers that
are formed are 141 flowers but none of them are filled pods. The cause of pods has no content because of the failure of pod formation due to weather that often rains and susceptible seeds. The highest non-covert results in P2 plot were 217 pods formed, the number of flowers was 252 flowers while the successful pods had 64 pods. The successful pod contained the highest P1 plot of 90 pods (Table 4).

| Tabel 4. Percentage of flower formed pod |
|-------------------------------|-----------------|-----------------|-----------------|
| Cover Treatments | Number of flowers | Number of pods | Flower formed pod (%) |
| Covered         | 168              | 146             | 87              |
| P1              | 150              | 111             | 74              |
| P2              | 159              | 131             | 82              |
| P3              | 141              | 81              | 57              |
| Uncovered       | 208              | 146             | 85              |
| P0              | 214              | 111             | 86              |
| P1              | 252              | 131             | 86              |
| P2              | 254              | 81              | 78              |

The treatment does not contain a lid which shows that soybeans can pollinate assisted by insects. Treatment of hoods will make it difficult for insects to help pollinate. So that the number of flowers formed into pods is less than not a lid. Plants covered with fruit and fruit quality were low compared to open plants because the plants were covered with no insects that helped pollinate [21]. The flowers of tomato plants that were closed failed to experience fruit formation compared to open flowers because there was a decrease in pollen viability because it was not pollinated [22]. Planting flowering plants can affect the percentage of soybean pods. This is indicated by an increase in the number of pods from planting without flowering plants and flowering plants. The increase in the number of pods is also comparable to the increase in the number of insect visitors visiting the treatment plot. The number of successful pods from crosses can be filled pods, empty pods that are affected by the high crossing, hence the success of tall pods [23]. Soybean yields do not get the weight of the pod because the pods have not been successfully filled due to submerged water. Soybeans will experience O2 deficiency and experience physiological and physical damage. Grobogan soybean varieties that experienced puddle stress in the vegetative phase experienced severe weight loss up to 60.41% [24].

4. Conclusion

Based on the results and discussion, the following conclusions are planting flowering plants can increase the insect population of visitors to soybean flowers but not by insect types. The number of types of insect flower visitors is influenced by the type of flowering plants. Insect flower visitors visit more ornate flowers than rosella flowers. Planting flowering plants can increase the number of pods.

References

[1] Milfont M O, Rocha E E M and Lima A O N 2013 *J. Env. Chem. Letters* **11** 335–341 DOI 10.1007/s10311-013-0412-8
[2] Chiari W S, Toledo V and Takasuki M C C 2005 *J. Brazilian Archive Bio. Tech.* **48** 31–36A
[3] Menz M H M, Phillips R D and Winfree R 2011 *Trends Plant Sci.* **16** 4–12
[4] Martin P and Bateson P 1993 *Measuring Behaviour An Introductory Guide* 2nd Ed (Cambrige: Cambridge Univ. Press)
[5] Siregar A S, Bakti D and Zahara F 2014 *J. Agroekoko* **24** 1640–1647 ISSN No 2337- 6597
[6] Yuliani W, Dahelmi and Syamsuardi 2013 *J. Bio. U/A* **2** 96–102
[7] Triplehorn C A and Johnson NF 2005 *Borror and Delong’s Introduction to the Study of Insects* (USA: Brooks Cole Thomson Learning Inc)
[8] Ramirez L, Jose G and Ayala, R 2012 *J.Pollin.Eco.* **1** 1–4
[9] Maulana R 2009 *Komunitas Serangga Penyerbuk Pada Habitat Dan Jarak Yang Beragam Dari Tepi HutanTaman Nasional Gunung Halimun Salak* Skripsi (Bogor: Fakultas
[10] Jumar 2000 Entomologi Pertanian (Jakarta: Rineka Cipta)
[11] Suzery M, Lestari S and Cahyono B 2010 J. Sains Matematika 18 1–6 ISSN 0854-0675
[12] Avargues-Weber A and Chittka L 2014 PloS ONE 9 88415
[13] Dotter S and Vereecken N J 2010 Can. J. Zool 88 668–697
[14] Wratten D S, Gillespie M, Decortye A, Mader E and Desneux N 2012 Agric. Eco.Env. 159 112–12
[15] Chasanah R L 2010 Keanekaragaman dan frekuensi kunjungan serangga penyerbuk serta efektivitasnya dalam pembentukan buah hoya multiflora blume (asclepiadaceae) Thesis (Bogor: Institut Pertanian Bogor)
[16] Mustakim A, Leksono A S and Kusuma Z 2014 Nat. Biosci. 2 248–253
[17] Faheem M, Aslam M and Razaq M 2004 J. Res. Sci. 4 395–409
[18] Dudareva N and Pichersky E 2006 Taylor and Francis Soc 61 325–336 DOI 10.1007/s00040-014-0366-2
[19] Stein K and Hensen I 2011 J. Poll. Eco. 4 39–47
[20] Sahli H F and Conner J K 2007 Am. J. Bot. 94 203–209
[21] Hasan P A, Atmowidi T and Kahono S 2017 J. Ento. Indo. 14 1–9 ISSN 1829-7722 DOI 10.5994/jei14 1 1
[22] Indraswari A G M, Atmowidi T and Kahono S 2016 J. Ento. Indo. 13 21–29 ISSN 1829-7722 DOI 10.5994/jei13 1 21
[23] Lubis N A, Rosmayati and Hanafiah D S 2015 Jurnal Online Agroek. 3 291–298 ISSN No 2337-6597
[24] Fatimah V S and Saputro T B 2016 J. Sains dan Seni ITS 5 2337–3520