Distance of agricultural land from natural habitat affects the functional trait diversity and species diversity but not abundance of Hymenoptera parasites

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Abstract. In agricultural landscapes, natural habitat may enhance species diversity or the abundance of natural enemies in arable lands, and thereby suppress pest populations effectively. However, there is a lack of studies in Tropical regions about these interactions. The aim of this study was to investigate the community structure of Hymenoptera parasites at two distances (<200 m and > 400 m) from edges of natural habitat to cucumber fields. This research was carried out in twelve cucumber fields in West Java, Indonesia. Hymenopteran parasites were collected by yellow pan trap and hand picking of parasitized lepidopteran larvae. In total, 19 family and 130 parasitoid species, comprising 19,167 individuals, were collected in our experiments. A number of 56 (43.1%) hymenopteran parasites species found only in cropping with a certain distance away from the natural habitat. Of these, as many as 39 species (69.6%) hymenopteran parasites found in cucumber fields within close natural habitats, while the crop is being of natural habitats found 17 species (13.1%). Moreover, the functional diversity of hymenopteran parasites tends to increase on cropland closed to natural habitat. We conclude that distance of agricultural land to natural habitat affect hymenopteran parasites.

1. Introduction

In developing countries, such as Indonesia, generally increasing agricultural production is carried out with the approach of agricultural intensification (i.e pesticide use) and extensification (i.e conversion of forest or semi-natural habitat into agricultural landscape). But on the other side, changes in landscape composition can trigger a decline in biodiversity and have negative impact on water, soil and ecosystem [1-3] and thereby possibly agricultural yields [4]. Moreover, simplification of agricultural landscape has caused ecosystem services such as crop pollination, biological control, and nutrient cycling does not work properly [5]. Thus, crop management is based on on use pesticides, chemical fertilizers, superior varieties, and genetically engineered seed. This agricultural intensification practices can influence the composition, abundance and distribution of insect species in agroecosystems [6-8].

The availability of natural habitats, such as shrubs and trees, in the agricultural landscape must be maintained because it can increase the number of parasitoids and predators and also can improve biological control. The natural habitat provides alternative prey and hosts, nectar and pollen resources for natural enemies [9-10], and refuges against unfavourable weather conditions [11-12]. In the spill
over hypothesis it has been explained that in agricultural landscapes close to natural habitats, biological control will increase because parasitoids and predators from natural habitat will overflow to these crop fields [13]. Biological control in agricultural landscapes increases with increasing proximity of natural habitat to agricultural crops [14-15]. But this is not consistent because some researchers report the opposite. Thomson et al. [16] reported that the effect of vineyard distance on tree habitats increased the abundance of Eulophidae, but instead decreases the population of Trichogrammatidae and Mymaridae. While the effect on the abundance of Coccinellidae and Neuroptera is not consistent. This shows that the effect of distance from natural habitats on natural enemies is species-specific. Coccinellidae and Neuroptera are predatory generalist groups that can use a variety of available resources in plantations so that to meet their needs there is no need to look into natural habitat [13, 17]. Bortolotto et al. [18] reported that the effect of distance from natural habitat to crop fields on plant abundance and parasitization rate is influenced by differences in regions (subtropical climates and temperate climates) and cultivation systems. Considering that most of the research on the influence of the distance between plantations from natural habitats is carried out in areas that have climate and cultivation systems that are different from Indonesia, the same study needs to be conducted in Indonesia.

In landscape studies, many studies document the effect of natural habitat on biodiversity. Two comprehensive reviews demonstrate that agricultural landscape contains the amount of non-crop habitats generally natural enemies are more abundant and diverse, but there is little evidence for effect on both pest abundance and diversity [19, 20]. This suggest that the presence of the amount of natural habitats in agricultural landscapes does not guarantee effective biological control even though natural enemies abundant and varied in the landscape [20]. Therefore, in this study we also measured functional trait diversity. Functional trait diversity is the dimension of biodiversity most directly related to ecosystem functioning [21, 22]. Furthermore, the ecosystem services provided by insects are influenced by its functional diversity [23]. The aims of study were to (i) studied the impact of crop fields distances from natural habitats on abundance, diversity, community structure, and species composition of Hymenoptera parasitic and (ii) measured the response of body size, wing span, length of hind tibia, head width as well as functional diversity to the different distance to natural habitats.

2. Materials and Methods

2.1. Study sites

Study was conducted in agricultural landscape in West Java, Indonesia (see Figure 1). The region consists of crop fields and natural habitat mosaic which is dominated by intensive agricultural landscapes and by patchily distributed fragments of natural habitat (such as shrubs and trees).

Within the region, 12 cucumber fields were selected based on distance to natural habitat, namely near to natural habitat (less than 200 m) and far from natural habitat (more than 400 m). The cucumber fields were varied in altitude and crop management. The distances between study sites were at least 3 km.

2.2. Insect sampling and identification

Parasitoids were collected from fields when plants were in vegetative and generative stage (November 2014 – May 2015). The immature stage of cucumber moth was collected using hand-picking method (200 plant per site), while adult wasps using yellow pan trap (three pans per site). All specimens were identified to morphospecies using identification handbooks [24-26] and compared with voucher specimens at the Laboratory of Insect and other Arthropod Taxonomy, Indonesian Institute of Science.

Morphometric of all adult parasitoids and hyperparasitoids were measured using tpsDig version 2 such as body size, wing span, length of hind tibia and head width. The functional diversity was calculated based on value of Community Weighted Mean (CWM = \( \sum_{i=1}^{n} p_i x_i \)), where \( p_i \) is the relative abundance of species \( i \) in a specific transect and \( x_i \) is the trait value of species \( i \) [27].
2.3. Statistical analysis
To determine the effects of the crop fields distance from natural habitats on diversity, number of species and functional diversity, we used an analysis of variance. Bray-Curtis dissimilarity index and non-metric multidimensional scaling (NMDS) were used to compare community structure of Hymenoptera parasitic on different distance crop field from natural habitat. While to determine the effects of the crop fields distance from natural habitats on community composition, we used the analysis of similarity test (ANOSIM) [28]. Statistical analyses were performed using R statistic [29].

3. Results and Discussion

3.1. Hymenoptera parasitic species richness and abundance in cucumber fields
During study we counted a total of 19 167 Hymenoptera parasitic belong to 19 families and 130 species (Appendix 1). The most frequently encountered parasitoid was species from family Scelionidae (18 species), Braconidae (15 species), Diapriidae (14 species) and Ichneumonidae (12 species). While, the most abundant was family Braconidae, Ceraphronidae and Ichneumonidae. Family Braconidae was dominated by Apantales taragamae, where the species was obtained from the results of its host collection.

3.2. Effect of crop field distance from natural habitat on the Hymenoptera parasitic abundance and diversity
Crop fields distance from natural habitat did not influence Hymenoptera parasitic abundance (ANOVA, $F_{1,10}= 4.00, P= 0.073$) and species richness of Hymenoptera parasitic ($F_{1,10}= 4.86, P= 0.052$) in cucumber fields (Table 1). However, species accumulation curves show differences in diversity of Hymenoptera parasitic between the different cucumber fields (Figure 2).

Bray-Curtis index showed that composition of Hymenoptera parasitic species in cucumber fields that are far and close to natural habitats had higher similarity (Table 2). We recorded 39 species only in the cucumber fields near to natural habitat, and 17 species in the fields located far from natural habitat.
(Figure 3, Appendix 1). Nevertheless, species composition of Hymenoptera parasitic among fields located far from natural habitats was more similar than fields located near to natural habitat (Figure 4).

| Variable          | Near | Far  | Significance       |
|-------------------|------|------|--------------------|
| Number of family  | 18   | 17   |                    |
| Species richness  | 112  | 92   | $F_{1,10} = 4.86$, $P = 0.052$ |
| Abundance         | 13122| 3613 | $F_{1,10} = 4.00$, $P = 0.073$ |

| Figure 2. Species accumulation curves of Hymenoptera parasitic found at cucumber field located at different distances from natural habitat. |

3.3. Effect of crop field distance from natural habitat on the functional trait diversity of Hymenoptera parasitic
Community-Weighted Mean (CWM) of Hymenoptera parasitic trait was significantly higher in cucumber field located near to natural habitats, for body length ($F_{1,10} = 6.61$, $P = 0.028$), fore wing ($F_{1,10} = 6.08$, $P = 0.033$), hind wing ($F_{1,10} = 6.18$, $P = 0.032$), length of tibia ($F_{1,10} = 5.91$, $P = 0.035$), and head width ($F_{1,10} = 6.63$, $P = 0.028$) (Figure 5). These indicated that the distance of crop fields from natural habitat had a negative impact on the functional diversity of Hymenoptera parasitic.

The abundance of Hymenoptera parasitic tends to decrease with increasing cucumber plantations from natural habitat. The same has been reported by several researchers [13, 30]. The rate of visit of pollinating insects on flowers decreases with increasing distance from natural habitats [31]. This impact is seen more clearly in tropical climates compared to temperate regions. This is caused by differences in the types of insect pollinators in the area.

| Table 2. Dissimilarity of Hymenoptera parasitic species (Bray-Curtis index) between cucumber fields near (front letter N) and far (front letter F) from natural habitat. |

| Fields located | N1 | N2 | N3 | N4 | N5 | N6 | F1 | F2 | F3 | F4 | F5 | F6 |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|
| N1            | 0  |    |    |    |    |    |    |    |    |    |    |    |
| N2            | 0.92 | 0  |    |    |    |    |    |    |    |    |    |    |
| N3            | 0.20 | 0.88 | 0  |    |    |    |    |    |    |    |    |    |
| N4            | 0.53 | 0.82 | 0.39 | 0  |    |    |    |    |    |    |    |    |
| N5            | 0.88 | 0.53 | 0.83 | 0.69 | 0  |    |    |    |    |    |    |    |
| N6            | 0.65 | 0.78 | 0.59 | 0.39 | 0.60 | 0  |    |    |    |    |    |    |
| F1            | 0.84 | 0.54 | 0.80 | 0.67 | 0.32 | 0.52 | 0  |    |    |    |    |    |
| F2            | 0.79 | 0.75 | 0.71 | 0.53 | 0.44 | 0.32 | 0.36 | 0  |    |    |    |    |
| F3            | 0.80 | 0.63 | 0.75 | 0.61 | 0.37 | 0.42 | 0.26 | 0.25 | 0  |    |    |    |
| F4            | 0.68 | 0.79 | 0.58 | 0.29 | 0.58 | 0.18 | 0.56 | 0.31 | 0.47 | 0  |    |    |
| F5            | 0.90 | 0.47 | 0.87 | 0.75 | 0.39 | 0.69 | 0.35 | 0.56 | 0.52 | 0.68 | 0  |    |
| F6            | 0.97 | 0.71 | 0.96 | 0.90 | 0.73 | 0.91 | 0.74 | 0.88 | 0.82 | 0.91 | 0.62 | 0  |

**Figure 3.** Diagram Venn of the number of species Hymenoptera parasitic found at cucumber fields located at different distances from natural habitat.

**Figure 4.** Composition of Hymenoptera parasitic species in cucumber fields, in nonmetric multidimensional scaling (NMDS) ordination (based on Bray-Curtis dissimilarity index). Cucumber fields near natural habitat are denoted by an N as first letter and far from natural habitat with F.
Although crop fields distance from natural habitat did not influence parasitoid diversity, but the increase in functional diversity along with the increasing distance of planting from natural habitats is consistent for all the morphological characteristics of the Hymenoptera parasitic. The results of this study are in accordance with Forrest et al. [32] which explains that agricultural habitats can interfere with the functional diversity of flying insects. Furthermore Geslin et al. [33] reported the negative effects of isolating agricultural habitats from natural habitats on the abundance and functional diversity of flying insects, even though they were in high biodiversity habitats. According to Gagic et al. [34], the role of this functional diversity in ecosystem services is more important than the contribution of species diversity to ecosystem services. The low functional diversity causes the pollination process to be inefficient [23, 32] and ultimately causes manga crop production to decline [35-36].

**Figure 5.** Box plots of community weighted mean (CWM) of Hymenoptera parasitic trait in cucumber fields located at different distance from natural habitat. (a) body size, (b) fore wing, (c) hind wing, (d) length of hind tibia, and (e) head width.
4. Conclusion

The distance of cucumber plantations from natural habitats does not affect the diversity and abundance of the Lepidoptera, primary parasitoid and hyperparasitoid communities in these plants. However, the distance of cucumber plantations from natural habitats affected the percentage of parasitic D. indica. The diversity and abundance of Hymenoptera parasitics tends to increase with the close proximity of cucumber plantations from natural habitats. The functional diversity of Hymenoptera parasitics tends to increase with the approach of planting land to natural habitat.

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### Appendix 1. Hymenoptera parasitic species sampled in both near and far sites from natural habitat

| No | Family | Distance from natural habitat | No | Family | Distance from natural habitat |
|----|--------|-------------------------------|----|--------|-------------------------------|
|    | Species | Near  | Far  |    | Species | Near  | Far  |
| 1. | *Aphelinus* sp. | +    | +    | 37. | *Diplolepis* sp. | +    | +    |
| 2. | *Apwyts* sp. | +    | +    | 38. | *Basalys* sp. | +    | +    |
| 3. | *Encarsia formosa* | +    | +    | 39. | *Chilomicrus* sp.01 | +    | +    |
| 4. | *Encarsia sp.01* | +    | +    | 40. | *Chilomicrus* sp.02 | +    | +    |
| 5. | *Encarsia sp.02* | +    | +    | 41. | *Coptera holoptera* | +    | +    |
| 6. | *Eremocerus* sp. | +    | +    | 42. | *Idiotypea* sp. | +    | +    |
| 7. | *Apanteles taragamae* | +    | +    | 43. | *Pentapria* sp.01 | +    | +    |
| 8. | *Aphytis* sp. | +    | +    | 44. | *Pentapria* sp.02 | +    | +    |
| 9. | *Encarsia formosa* | +    | +    | 45. | *Polypeza* sp.01 | +    | +    |
| 10. | *Encarsia formosa* | +    | +    | 46. | *Polypeza* sp.02 | +    | +    |
| 11. | *Apanteles* sp. | +    | +    | 47. | *Polypeza* sp.03 | +    | +    |
| 12. | *Apanteles* sp. | +    | +    | 48. | *Polypeza* sp.04 | +    | +    |
| 13. | *Apanteles* sp. | +    | +    | 49. | *Spilomicrus* sp. | +    | +    |
| 14. | *Aphelinus* sp. | +    | +    | 50. | *Trichopria bipunctata* | +    | +    |
| 15. | *Aphelinus* sp. | +    | +    | 51. | *Trichopria drosophilae* | +    | +    |
| 16. | *Aphelinus* sp. | +    | +    | 52. | *Trichopria drosophilae* | +    | +    |
| 17. | *Aphelinus* sp. | +    | +    | 53. | *Trichopria drosophilae* | +    | +    |
| 18. | *Aphelinus* sp. | +    | +    | 54. | *Trichopria drosophilae* | +    | +    |
| 19. | *Aphelinus* sp. | +    | +    | 55. | *Trichopria drosophilae* | +    | +    |
| 20. | *Aphelinus* sp. | +    | +    | 56. | *Trichopria drosophilae* | +    | +    |
| 21. | *Aphelinus* sp. | +    | +    | 57. | *Trichopria drosophilae* | +    | +    |
| 22. | *Aphelinus* sp. | +    | +    | 58. | *Trichopria drosophilae* | +    | +    |
| 23. | *Aphelinus* sp. | +    | +    | 59. | *Trichopria drosophilae* | +    | +    |
| 24. | *Aphelinus* sp. | +    | +    | 60. | *Trichopria drosophilae* | +    | +    |
| 25. | *Aphelinus* sp. | +    | +    | 61. | *Trichopria drosophilae* | +    | +    |
| 26. | *Aphelinus* sp. | +    | +    | 62. | *Trichopria drosophilae* | +    | +    |
| 27. | *Aphelinus* sp. | +    | +    | 63. | *Trichopria drosophilae* | +    | +    |
| 28. | *Ceraphron* sp. | +    | +    | 64. | *Trichopria drosophilae* | +    | +    |
| 29. | *Ceraphron* sp. | +    | +    | 65. | *Trichopria drosophilae* | +    | +    |
| 30. | *Ceraphron* sp. | +    | +    | 66. | *Trichopria drosophilae* | +    | +    |
| 31. | *Ceraphron* sp. | +    | +    | 67. | *Trichopria drosophilae* | +    | +    |
| 32. | *Ceraphron* sp. | +    | +    | 68. | *Trichopria drosophilae* | +    | +    |
| 33. | *Ceraphron* sp. | +    | +    | 69. | *Trichopria drosophilae* | +    | +    |
| 34. | *Ceraphron* sp. | +    | +    | 70. | *Trichopria drosophilae* | +    | +    |
| 35. | *Ceraphron* sp. | +    | +    | 71. | *Trichopria drosophilae* | +    | +    |
| No | Family                        | Species          | Distance from natural habitat | No | Family                        | Species          | Distance from natural habitat |
|----|------------------------------|------------------|-------------------------------|----|------------------------------|------------------|-------------------------------|
|    |                              |                  | Near  | Far |                           |                  | Near  | Far |
| 72 | *Eupelmus* sp.               |                  | +     |     | 101. *Platygastrida*        | *Platygastrida*  |                  | +   |
|    | Eurytomidae                  |                  |       |     |                             |                  |       |     |
| 73 | *Eurytoma* sp.               |                  | +     |     | 102. *Asaphidae*            | *Asaphidae*      |                  | +   |
|    | Evanidae                     |                  |       |     |                             |                  |       |     |
| 74 | *Evania* sp.                 |                  | +     |     | 103. *Habrocytidae*         | *Habrocytidae*   |                  | +   |
|    | *Eurythoma* sp.              |                  |       |     |                             |                  |       |     |
| 75 | *Hyptia* sp.                 |                  | +     |     | 104. *Pteromalidae*         | *Pteromalidae*   |                  | +   |
|    | Ichneumonidae                |                  |       |     |                             |                  |       |     |
| 76 | *Acrocinus* sp.              |                  | +     |     | 105. *Trichomalopsis*       | *Trichomalopsis* |                  | +   |
|    | Amauromorpha* sp.            |                  |       |     |                             |                  |       |     |
| 77 | *Diadegma* sp.               |                  | +     |     | 106. *Baeus* sp.*           | *Baeus* sp.*     |                  | +   |
|    | Echthromorphidae             |                  |       |     |                             |                  |       |     |
| 78 | *Goryphus* sp.01 *           |                  | +     |     | 107. *Calliscelio* sp.01 *  | *Calliscelio* sp.01 * |                  | +   |
|    | *Ichneumon* sp.01 **         |                  | +     |     | 108. *Calliscelio* sp.02 *  | *Calliscelio* sp.02 * |                  | +   |
|    | *Ichneumon* sp.02 *          |                  | +     |     | 109. *Calotelea* sp.*      | *Calotelea* sp.* |                  | +   |
|    | *Phorotrophus* sp. *         |                  | +     |     | 110. *Ceratobaeus* sp.01 *  | *Ceratobaeus* sp.01 * |                  | +   |
|    | *Sictopisthus* sp.02 **      |                  | +     |     | 111. *Gryon* sp.*          | *Gryon* sp.*     |                  | +   |
|    | *Temelucha* sp."             |                  | +     |     | 112. *Macroteleia* spinitibia* | *Macroteleia* spinitibia* |                  | +   |
|    | *Xanthopimla* sp."**         |                  | +     |     | 113. *Platyscelio* sp.*    | *Platyscelio* sp.* |                  | +   |
|    | *Xorides* sp.                |                  | +     |     | 114. *Scelio* sp.01 *      | *Scelio* sp.01 * |                  | +   |
|    | Mymaridae                    |                  |       |     |                             |                  |       |     |
|    | *Anagrus* sp.                |                  | +     |     | 115. *Scelio* sp.02 *      | *Scelio* sp.02 * |                  | +   |
|    | *Anaphes* sp.                |                  | +     |     | 116. *Scelio* sp.03 *      | *Scelio* sp.03 * |                  | +   |
|    | *Cleruchus* sp.              |                  | +     |     | 117. *Telenomus podisi*    | *Telenomus podisi* |                  | +   |
|    | *Erythemelus* sp.            |                  | +     |     | 118. *Telenomus* sp.01 *   | *Telenomus* sp.01 * |                  | +   |
|    | *Gonatocerus* sp.            |                  | +     |     | 119. *Telenomus* sp.02 *   | *Telenomus* sp.02 * |                  | +   |
|    | *Mymar* sp.01 *              |                  | +     |     | 120. *Trichogramma* chilonis* | *Trichogramma* chilonis* |                  | +   |
|    | *Mymar* sp.02 *              |                  | +     |     | 121. *Trichogramma japonicum* | *Trichogramma japonicum* |                  | +   |
|    | *Polynema* sp.               |                  | +     |     | 122. *Trichogramma minutum* | *Trichogramma minutum* |                  | +   |
|    | Platygastridae               |                  |       |     |                             |                  |       |     |
|    | *Idris* sp.                  |                  | +     |     | 123. *Trichogrammatidae*    | *Trichogrammatidae* |                  | +   |
|    | *Inostemma* sp.              |                  | +     |     |                             |                  |       |     |
|    | *Platygastrida* sp.01 *      |                  | +     |     |                             |                  |       |     |
|    | *Platygastrida* sp.02 *      |                  | +     |     |                             |                  |       |     |
|    | *Platygastrida* sp.03 *      |                  | +     |     |                             |                  |       |     |