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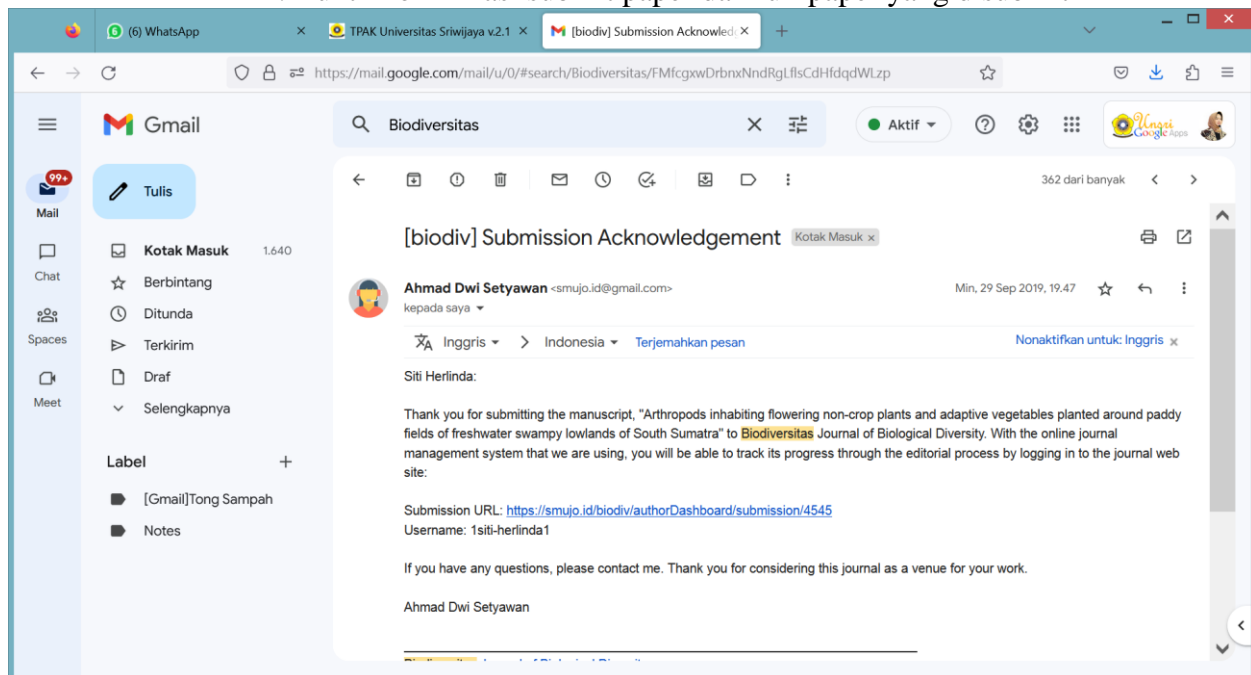
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Dear **Editor-in-Chief**,

I herewith enclosed a research article,

**Title:**

Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swampy lowlands of South Sumatra

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This study highlights several findings, such as we have found that some species of flowering non-crop plants and adaptive vegetables can be used for the conservation of natural enemies of rice insect pests. They are *Zinnia* sp., *T. erecta*, and *M. charantia*.

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Palembang, 29 September 2019

**Sincerely yours,**

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Siti Herlinda

# Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swampy lowlands of South Sumatra

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**Abstract.** Local farmers in freshwater swampy lowlands of South Sumatra traditionally plant adaptive flowering vegetables surrounding paddy fields and let flowering wild plants or non-crop plants grow on embankment. This research aimed to identify species and analyze the composition of arthropod guilds inhabiting non-crop plants and adaptive vegetables around the paddy fields in freshwater swampy lowlands. This field experiment used four species of flowering non-crop plants (*Zinnia* sp., *Tagetes erecta*, *Cosmos caudatus*, *Sesamum indicum*) and vegetables (*Vigna unguiculata*, *Momordica charantia*, *Cucumis sativus*, *Luffa acutangula*) planted around the paddy fields and the arthropods were collected using sweep nets. There were 24 species of predatory arthropods, three species of parasitoids, 17 species of herbivores, and nine species of neutral insects found in the non-crop plants and vegetables. The non-crop plant and vegetable species that were the most chosen by the predatory arthropods were *Zinnia* sp. and *M. charantia*, respectively. Species of the non-crop plants and vegetables chosen by the parasitoids were *T. erecta* and *M. charantia*, respectively. Those non-crop plants and adaptive vegetables were the most chosen plants by the predatory arthropods for their habitats and niches. Therefore, for the conservation of natural enemies it is better to use *Zinnia* sp., *T. erecta*, and *M. charantia*.

**Key words:** herbivores; neutral insects; parasitoids; predatory arthropods; predatory insects

**Abbreviations** (if any): -

**Running title:** Arthropods inhabiting flowering non-crop plants

## INTRODUCTION

Freshwater swampy lowlands are wetlands whose land is saturated with water, either throughout the year or seasonally due to the influence of river water or rain and in Indonesia they reach 9.2 Mha (Mulyani and Sarwani, 2013) spreading across Sumatra, Kalimantan, and Papua. Freshwater swampy lowlands have three land typologies, namely shallow, middle, and deep, generally cultivated as adaptive plants (Siaga et al. 2019). All the three land typologies are generally planted with paddy (Herlinda et al. 2018; Lakitan et al. 2018; Prabawati et al. 2019). For shallow and middle swampy lowlands, on paddy fields they are generally planted with adaptive vegetables, such as chili (Johari et al. 2014, 2016), long beans, bitter melon, cystic, eggplant, cucumber (Siaga et al. 2019). On embankments not planted with adaptive vegetables they are generally not weeded but wild plants (non-crop plants) can still grow there (Herlinda et al. 2019; Karenina et al. 2019). In addition, the local farmers are not accustomed to applying synthetic pesticides (Herlinda et al. 2018).

Unnoticed by the farmers, the wild vegetables and plants can act as habitats and arthropod niches both as natural enemies and insect pests (Hassan et al. 2016; McCabe et al. 2017). Apart from being alternative habitats and niches for natural enemies, these wild vegetables and plants also act as providers of nectar and pollen (Karenina et al. 2019). The nectar and pollen can increase the longevity, fecundity, and fitness of adult natural enemies (Desai et al. 2017; Foti et al. 2017).

In some species of flowering non-crop plants, for example *Zinnia* sp. spiders are found settling, and *Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp. (Desai et al. 2017). *Tagetes erecta* are inhabited by *Oxyopes javanus*, *Coccinella septempunctata*, *Syrphus* spp., *Geocoris* spp., *Apis dorsata*, *A. mellifera*, and *Vanessa cardui* (Ganai et al. 2017). The natural enemies of predatory arthropods, namely Pentatomidae and Mantidae and parasitoids from Eulophidae, Tachinidae, and Ichneumonidae are found in non-crop plants (*Antigonon leptopus*, *Turnera subulata*, and *Agreratum* sp.) (Saleh and Siregar 2017). Paddy of freshwater swampy lowlands surrounded by vegetables such as *V. sinensis*, *C. sativus*, *M. charantia*, and *L. acutangula* has an abundance and variety of species of arthropod predator more than that not surrounded

47 by the four vegetable species (Karenina et al. 2019). Consequently, it is necessary to find out the species of arthropods that  
48 inhabit non-crop plants and adaptive vegetables. The study aimed to identify the species of arthropods and analyze the  
49 composition of arthropod guilds inhabiting non-crop plants and adaptive vegetables surrounding the paddy fields of  
50 freshwater swampy lowlands.

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## MATERIALS AND METHODS

The study was carried out in the swampy lowland paddy fields of Pelabuhan Dalam Village in Pemulutan Subdistrict of Ogan Ilir District of South Sumatra Province from May to November 2018. The identification of arthropod species was conducted from December to March 2019 by Dr. Chandra Irsan. The location of the study was carried out in a swampy lowland paddy center surrounded by monoculture paddy on an area of 800 ha. In this study, 4 species of non-crop plants were planted in paddy fields surrounding 1 hectare of swampy lowland paddy and 1 hectare of the other paddy plots was surrounded by 4 species of local vegetables planted in embankment of paddy fields.

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### Growing Non-crop plants and vegetables

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The planting of non-crop plants and vegetables was carried out 30 days before planting paddy so that when it reached 14 days after transplanting (DAT), the non-crop plants and vegetables began to bloom. There were two paddy plots of 1 ha each. The first plot was surrounded by 4 species of non-crop plants: zinnia (*Zinnia* sp.), marigold (*Tagetes erecta*), kenikir (*Cosmos caudatus*), and sesame (*Sesamum indicum*) planted on four sides of the embankment. The second plot was surrounded by 4 species of vegetables: cowpea (*Vigna unguiculata*), bitter melon (*Momordica charantia*), cucumber (*Cucumis sativus*), and ridged gourd (*Luffa acutangula*). The spacing between planting holes was 30 cm for long beans, 60 cm for bitter melons, 40 cm for cucumbers, and 30 cm for ridged gourd. As for non-crop plants, the spacing between planting holes was 15 cm.

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### Paddy planting

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The stages of paddy planting started from tillage, seed treatment, nursery, transplanting, and fertilizing using manure and liquid compost extract. Land preparation and processing began with clearing weeds and then soil treatment while applying manure at a dose of 1 ton.ha<sup>-1</sup> and liquid compost extract at a dose of 2 L.ha<sup>-1</sup>. Liquid compost extract was made following the method of Suwandi et al. (2012) enriched with *Trichoderma virens*. The paddy seeds used *mekongga* varieties which were already treated using compost extract when ripening the seeds for 1 x 24 hours. After that, the seeds were sown and covered with banana leaf on a plastic tray (size 36 cm x 27 cm x 4.5 cm) for 14 days. The 14-day-old paddy seedlings were transplanted into the fields with the 2:1 *legowo* row system with a planting space of 50 cm x 25 cm x 12.5 cm.

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### Observation of arthropod inhabiting non-crop plants and vegetables

The observation of arthropod inhabiting non-crop plants and vegetables surrounding the paddy was conducted once a week starting when the paddy reached 14 to 84 days after transplanting (DAT). This observation was a continuation of the research of Karenina et al. (2019) who sampled by taking 5 flowers for each species of non-crop plants and vegetables, while in this study the sampling was carried out by observing directly and documenting arthropods that perched on non-crop plants flowers or leaves and vegetables at 07–08 a.m., 09–10 a.m., 12–01 p.m., and 04–05 p.m. Direct observations were conducted on 5 families for each species of non-crop plants and vegetables. The observations were made by recording and documenting the arthropods that perched. The inhabiting arthropods were identified based on their morphological characteristics. Identification of spiders referred to Barrion and Litsinger (1995) and identifying insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

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### Data analysis

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Arthropod composition and abundance data on non-crop plants and vegetables were analyzed descriptively and presented in tables and graphs. The arthropod abundance data were also further grouped by guild, namely predator (spiders and predatory insects), parasitoids, herbivores, and neutral insects to be displayed in graphical form.

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## RESULTS AND DISCUSSION

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### Arthropod abundance inhabiting non-crop plants and vegetables

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Dominant arthropods inhabiting non-crop plants and vegetables were *Cosmophasis* sp., *Tetragnatha mandibulata*, *Oxyopes javanus*, *Oxyopes* sp., *Odontoponera transversa*, *Menochilus sexmaculatus*, *Pantala* sp., and *Odontomantis planiceps* (Figure 1). The most dominant species of predatory arthropods at non-crop plants were *Odontomantis planiceps*, while at the vegetables they were Coccinellidae (unknown species). During one paddy planting season, 24 species of

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84 predatory arthropods (spiders and predatory insects) were found inhabiting non-crop plants and vegetables. The species of  
 85 non-crop plants most chosen by the predatory arthropods was zinnia (0.271 individuals/hill), while the adaptive vegetable  
 86 chosen was bitter melon (0.039 individuals/hill) (Table 1). The number of species of predatory arthropods in zinnia and  
 87 bitter melons was the largest, comprising 15 species and 6 species, respectively.  
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89 **Table 1.** Predatory arthropod abundance inhabiting non-crop plants and vegetables

| Species                            | Predatory arthropod abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |  |
|------------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|--|
|                                    | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |  |
| 1. <i>Pardosa</i> sp.              | 0.009   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |  |
| 2. <i>Argiope</i> sp.              | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |  |
| 3. <i>Tetragnatha virescens</i>    | 0   | 0        | 0       | 0      | 0.005  | 0            | 0        | 0            |  |
| 4. <i>Tetragnatha mandibulata</i>  | 0.023   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |  |
| 5. Linyphiidae (unknown sp.)       | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |  |
| 6. <i>Oxyopes matiensis</i>        | 0.032   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |  |
| 7. <i>Oxyopes javanus</i>          | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |  |
| 8. Thomisidae (unknown )           | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |  |
| 9. <i>Cosmophasis</i> sp.          | 0.045   | 0.018    | 0       | 0.014  | 0      | 0            | 0        | 0            |  |
| 10. Salticidae (unknown sp.)       | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |  |
| 11. <i>Menochilus sexmaculatus</i> | 0.014   | 0.005    | 0       | 0.005  | 0      | 0.014        | 0.009    | 0.009        |  |
| 12. Coccinellidae (unknown sp.)    | 0.005   | 0.009    | 0       | 0      | 0      | 0.005        | 0.018    | 0            |  |
| 13. <i>Formicomus</i> sp.          | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |  |
| 14. <i>Paederus fuscipes</i>       | 0.005   | 0        | 0       | 0      | 0      | 0.005        | 0        | 0            |  |
| 15. Chloropidae (unknown sp.)      | 0   | 0.032    | 0.005   | 0      | 0      | 0            | 0        | 0            |  |
| 16. <i>Chrysosoma leucopogon</i>   | 0.018   | 0.005    | 0       | 0      | 0      | 0.005        | 0        | 0            |  |
| 17. <i>Eristalinus</i> sp.         | 0.005   | 0        | 0       | 0      | 0      | 0.005        | 0        | 0            |  |
| 18. <i>Eristalis</i> sp.           | 0   | 0.009    | 0.018   | 0      | 0      | 0.005        | 0        | 0            |  |
| 19. <i>Ropalidia marginata</i>     | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0.005        |  |
| 20. <i>Odontomantis planiceps</i>  | 0.068   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |  |
| 21. <i>Archimantis</i> sp.         | 0   | 0        | 0.014   | 0      | 0      | 0            | 0        | 0            |  |
| 22. Mantidae (unknown sp.)         | 0.014   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |  |
| 23. <i>Pantala flavescens</i>      | 0.018   | 0.027    | 0       | 0.005  | 0      | 0            | 0        | 0.005        |  |
| 24. <i>Ictinogomphus</i> sp.       | 0   | 0        | 0       | 0      | 0      | 0            | 0        | 0.005        |  |
| Total of abundance                 | 0.271   | 0.11     | 0.057   | 0.039  | 0.005  | 0.039        | 0.027    | 0.024        |  |
| Total of species                   | 15  | 8        | 7       | 6      | 1      | 6            | 2        | 4            |  |

90 **Table 2.** Parasitoids abundance inhabiting non-crop plants and vegetables  
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| Species                        | Parasitoids abundance inhabiting non-crop plants dan vegetables (individual/hill) |          |         |        |        |              |          |              |  |
|--------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|--|
|                                | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |  |
| 1. <i>Cryptochetum iceryae</i> | 0.009   | 0.014    | 0.014   | 0.005  | 0.005  | 0            | 0        | 0            |  |
| 2. Sarcophagidae (unknown sp.) | 0.009   | 0.018    | 0.009   | 0.005  | 0.005  | 0.014        | 0        | 0            |  |
| 3. <i>Blondelia nigripes</i>   | 0.014   | 0.018    | 0.023   | 0      | 0      | 0.005        | 0        | 0.005        |  |
| Total of abundance             | 0.032   | 0.05     | 0.046   | 0.01   | 0.01   | 0.019        | 0        | 0.005        |  |
| Total of species               | 3   | 3        | 3       | 2      | 2      | 2            | 0        | 1            |  |

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 94 The parasitoids species found in non-crop plants were a large number of *Blondelia nigripes*, while those found in  
 95 vegetables were *Sarcophagidae* (Table 2). During the paddy planting season, there were found 3 species of parasitoid  
 96 families inhabiting the non-crop plants and vegetables. The highest parasitoid abundance in non-crop plants was found in  
 97 *zinnia* and the highest parasitoid abundance in vegetables was found in bitter melons.

98 Species of herbivores or phytophagous species found in non-crop plants were *Pelopidas thrax*, while the species most  
 99 commonly found in vegetables was *Aulacophora frontalis* (Table 3). During the paddy planting season, 17 species of  
 100 herbivores were found inhabiting non-crop plants and vegetables. The highest abundance of herbivores in non-crop plants  
 101 was found in *zinnia* and the highest abundance of herbivores in vegetables was found in ridged gourd.

102 The species of neutral insects found in non-crop plants and vegetables was *Odontoponera transversa*. During the  
 103 paddy planting season, 9 species of neutral insects were found inhabiting non-crop plants and vegetables (Table 4). The  
 104 highest abundance of neutral insects in non-crop plants was found in sesame and the highest abundance of neutral insects  
 105 in vegetables was found in cowpeas.  
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107 **Table 3.** Herbivore abundance inhabiting non-crop plants and vegetables

| Species                          | Herbivore abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|----------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                  | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |
| 1. <i>Chrysolina coeruleans</i>  | 0.018   | 0        | 0.005   | 0.005  | 0      | 0.014        | 0.009    | 0.009        |
| 2. <i>Aulacophora frontalis</i>  | 0   | 0.005    | 0       | 0      | 0      | 0.073        | 0.014    | 0.482        |
| 3. <i>Aulacophora indica</i>     | 0   | 0        | 0       | 0      | 0      | 0.005        | 0.151    | 0            |
| 4. <i>Charidotella</i> sp.       | 0   | 0        | 0       | 0      | 0      | 0            | 0.005    | 0            |
| 5. <i>Epilachna dodecastigma</i> | 0   | 0        | 0       | 0      | 0      | 0.059        | 0.005    | 0.023        |
| 6. <i>Cletus trigonus</i>        | 0.036   | 0.009    | 0.005   | 0      | 0      | 0.032        | 0        | 0            |
| 7. <i>Amata nigriceps</i>        | 0.018   | 0.045    | 0       | 0      | 0.018  | 0.050        | 0.009    | 0            |
| 8. <i>Petrophora</i> sp.         | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 9. <i>Perizoma</i> sp.           | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |
| 10. <i>Pelopidas thrax</i>       | 0.291   | 0.041    | 0.036   | 0      | 0      | 0.077        | 0.005    | 0            |
| 11. <i>Spodoptera</i> sp.        | 0.009   | 0        | 0       | 0      | 0      | 0.009        | 0        | 0            |
| 12. <i>Eurema blanda</i>         | 0.009   | 0        | 0.023   | 0      | 0      | 0.014        | 0        | 0            |
| 13. <i>Aporia</i> sp.            | 0.009   | 0.009    | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 14. <i>Valanga nigricornis</i>   | 0.123   | 0.041    | 0.032   | 0.045  | 0      | 0.050        | 0.100    | 0            |
| 15. <i>Acrida turrata</i>        | 0.032   | 0.023    | 0.005   | 0.014  | 0      | 0            | 0        | 0.005        |
| 16. <i>Oxya chinensis</i>        | 0.041   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 17. <i>Tetrix subulata</i>       | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| Total of abundance               | 0.591   | 0.178    | 0.116   | 0.064  | 0.018  | 0.383        | 0.298    | 0.519        |
| Total of species                 | 11  | 8        | 8       | 3      | 1      | 10           | 8        | 4            |

108 **Table 4.** Neutral insect abundance inhabiting non-crop plants and vegetables  
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| Species                           | Neutral insect abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|-----------------------------------|--|----------|---------|--------|--------|--------------|----------|--------------|
|                                   | zinnia   | marigold | kenikir | sesame | cowpea | bitter melon | cucumber | ridged gourd |
| 1. Chironomidae (unknown sp.)     | 0.005  | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 2. <i>Rainieria antennaepes</i>   | 0.036  | 0.014    | 0.023   | 0.009  | 0.005  | 0            | 0.005    | 0.005        |
| 3. <i>Neomyia cornicina</i>       | 0.009  | 0.005    | 0.018   | 0.027  | 0      | 0            | 0        | 0            |
| 4. <i>Chloromyia farnosa</i>      | 0.005  | 0        | 0.014   | 0      | 0      | 0            | 0        | 0.005        |
| 5. <i>Hermetia</i> sp.            | 0.005  | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 6. <i>Tipula maxima</i>           | 0.045  | 0.009    | 0.014   | 0.005  | 0      | 0            | 0.005    | 0            |
| 7. <i>Trigona</i> sp.             | 0.118  | 0.082    | 0.023   | 0      | 0      | 0.055        | 0        | 0.005        |
| 8. <i>Apis cerana</i>             | 0  | 0.014    | 0       | 0      | 0      | 0            | 0        | 0            |
| 9. <i>Odontoponera transversa</i> | 0  | 0.009    | 0       | 0.273  | 0.815  | 0            | 0        | 0.345        |
| Total of abundance                | 0.223  | 0.133    | 0.092   | 0.314  | 0.82   | 0.055        | 0.01     | 0.36         |
| Total of species                  | 7  | 6        | 5       | 4      | 2      | 1            | 2        | 4            |

110 **Arthropod community and guilds inhabiting non-crop plants and vegetables**  
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112 The arthropod community inhabiting non-crop plants and vegetables varied between plant species. Guild of herbivores  
 113 were predominantly found in 3 species of non-crop plants (*zinnia*, marigolds, *cosmos caudatus*) and 3 vegetable species  
 114 (bitter melons, cucumber, and ridged gourd), but they were not dominant in others and cowpeas (Figure 2). The sesame  
 115 and cowpea were dominated by a neutral insect community, primarily *Odontoponera transversa*.

116 The arthropod community inhabiting non-crop plants and vegetables varied between plant species (Figure 3). They  
 117 were dominated by 4 families, namely *Hesperidae*, *Apidae*, *Formicidae*, and *Chrysomelidae*. Arthropods inhabiting *zinnia*  
 118 and *cosmos caudatus* were dominated by the *Hesperidae* Family; the marigolds were dominated by the *Apidae* Family; the

119 sesame and cowpea were dominated by *Formicidae*; and the bitter melon, cucumber and ridged gourd were dominated by  
120 *Chrysomelidae*.

121 The highest abundance of guilds of predators inhabiting non-crop plants was found in zinnia. The high abundance of  
122 predators inhabiting zinnia was followed by that of herbivores and neutral insects (Figure 4). There was a link among the  
123 abundance of predators, herbivores, and neutral insects inhabiting the plants. The highest abundance of predators  
124 inhabiting vegetables was found in bitter melons, followed by high abundances of parasitoids and herbivores. The high  
125 abundance of predators in bitter melons was not followed by that of neutral insects. The abundance of neutral insects in  
126 vegetables was found in cowpeas.

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168 **Figure 1.** Dominant arthropod species inhabiting non-crop plants and vegetables: *Cosmophasis* sp. (A), *Tetragnatha mandibulata* (B),  
169 *Oxyopes javanus* (C), *Oxyopes* sp. (D), *Odontoponera transversa* (E), *Menochilus sexmaculatus* (F), *Pantala* sp. (G), *Odontomantis*  
170 *planiceps* (H), *Pelopidas* sp. (I), *Amata nigripes* (J), *Aulacophora indica* (K), *Valanga nigricornis* (L), *A. frontalis* (M), *Tipula* sp. (N),  
171 *Trigona* sp. (O), and *Rainieria antennaepe* (P)

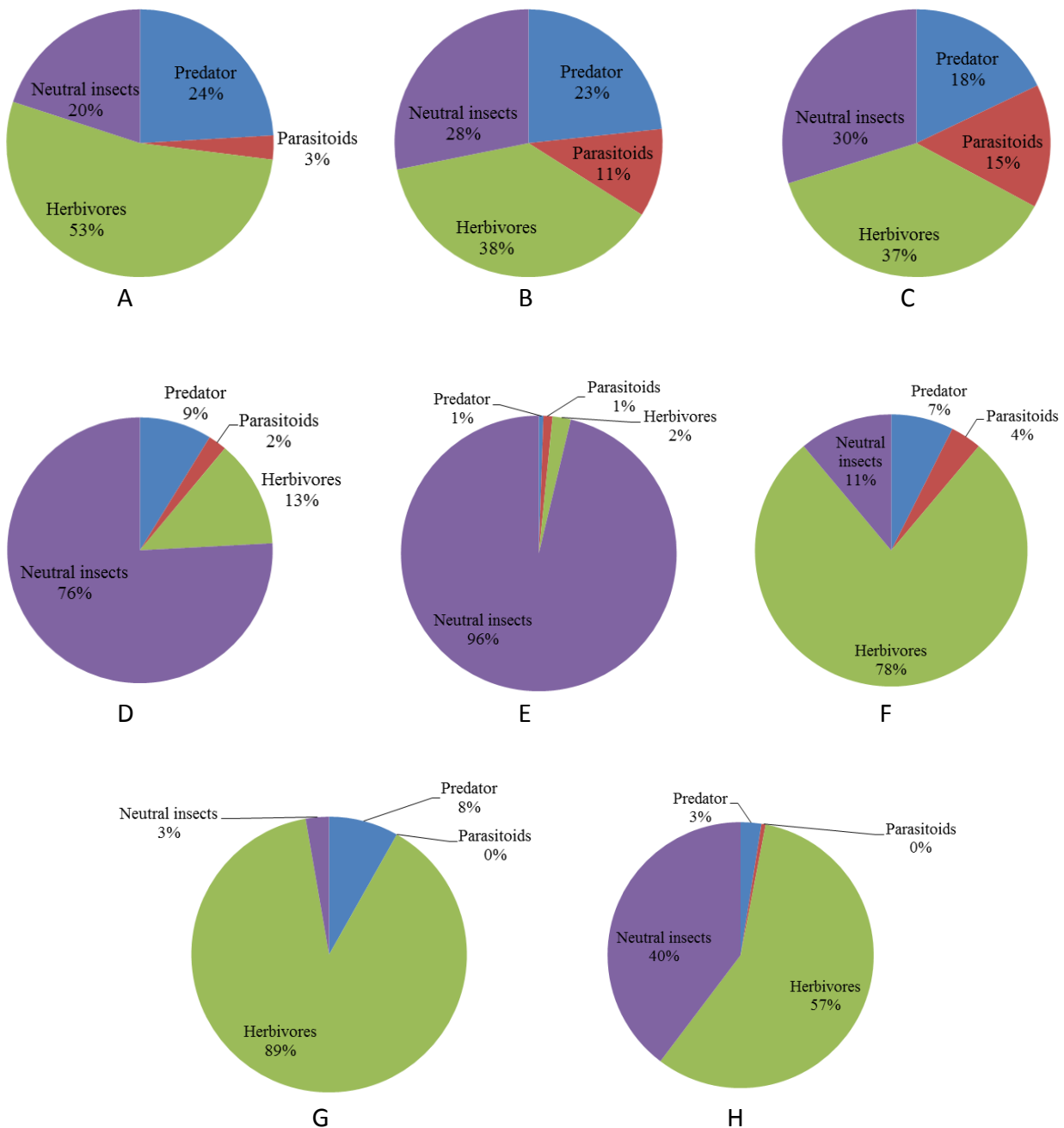
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173 The abundance of 4 community guilds of arthropods inhabiting non-crop plants and vegetables had a different  
174 tendency (Figure 5). Predators could visit non-crop plants and vegetables all day from morning to evening. Zinnia tended  
175 to be visited by predators in the afternoon and evening, *cosmos caudatus* in the morning and evening, cowpea and bitter  
176 melon in the morning, and ridged gourd in the afternoon and evening. Parasitoids generally visited non-crop plants and  
177 vegetables in the morning, for example Zinnia, marigolds, sesame, and bitter melons were visited at 07–08 a.m., while  
178 *cosmos caudatus* and cowpea were mostly visited at 09–10 a.m. However, ridged gourd was visited by parasitoids in the

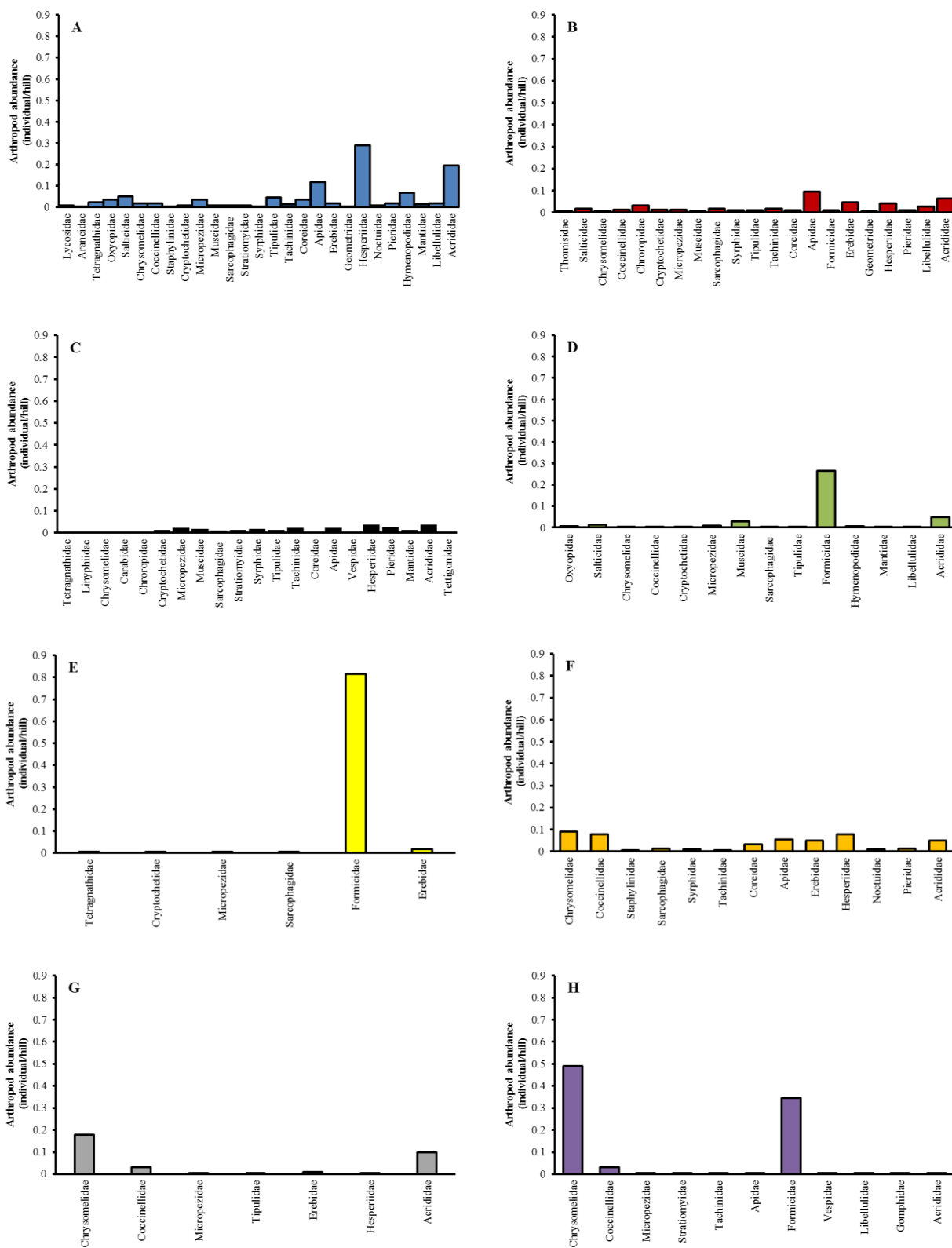


179 afternoon at 04-05 p.m. Among those flowers, the marigolds were the most chosen by the parasitoids. Herbivores visited  
 180 non-crop plants and vegetables throughout the day, while many neutral insects visited non-crop plants and vegetables in  
 181 the morning.

182 The abundance of guild arthropods found in non-crop plants and vegetables fluctuated during one paddy planting  
 183 season. When paddy was initially planted, the abundance of arthropods found in non-crop plants and vegetables tended  
 184 to be lower and continued to increase and reached a peak in the ripe phase of milk (56-70 DAT), nearing the harvest it tended  
 185 to decline. During one planting season, the abundance of guilds of herbivores in zinnia, bitter melons, cucumber, and  
 186 ridged gourd was always higher compared to other guilds, whereas in sesame and cowpeas, the abundance of neutral  
 187 insects was always high (Figure 6). The abundance of guilds of predators and parasitoids was highest in zinnia, while in  
 188 other plants the abundance of both guilds was lower. The abundance of predators tended to be affected by the fluctuations  
 189 of herbivores abundance.

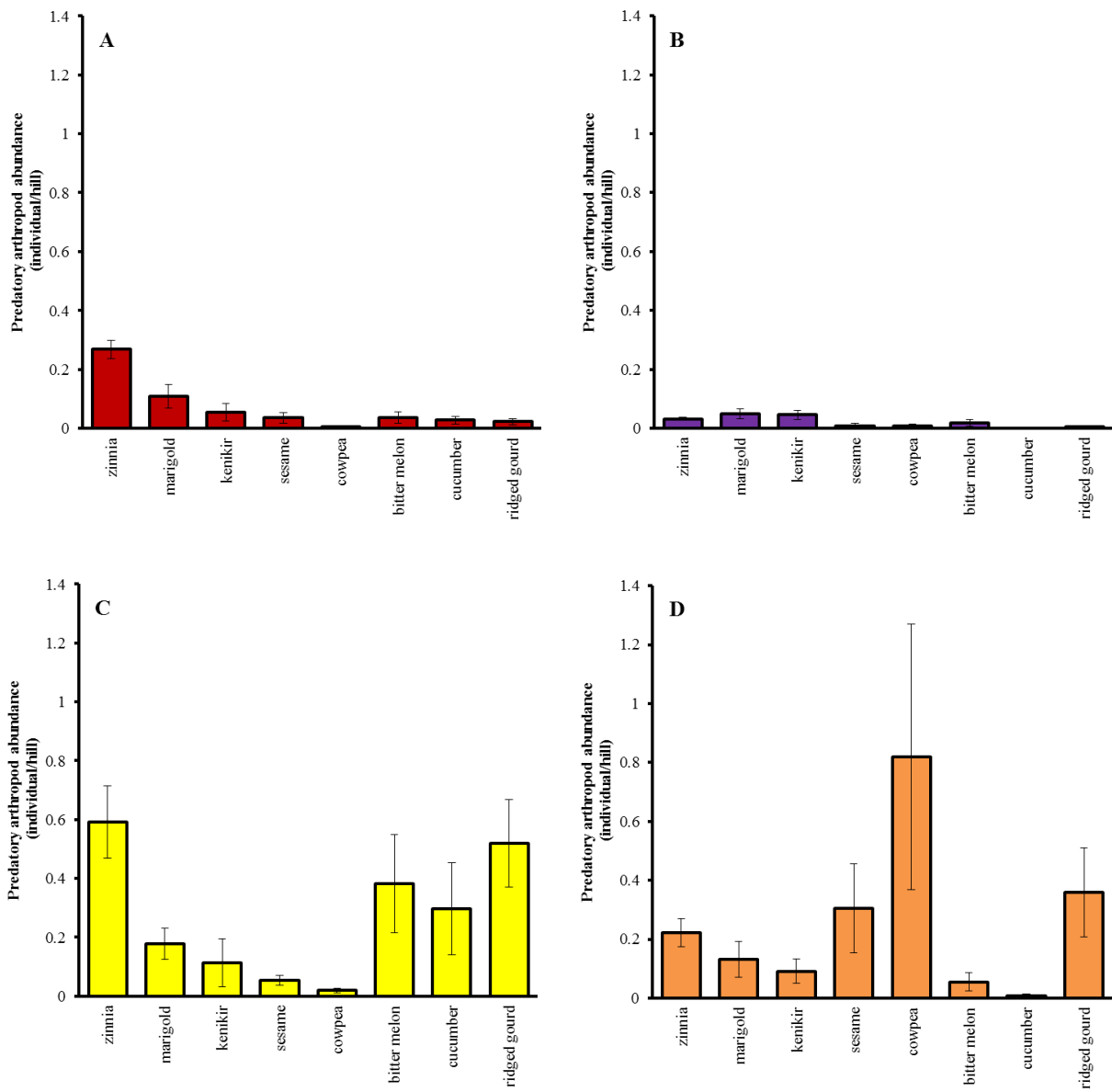


230 **Figure 2.** Proportion of arthropod guilds inhabiting non-crop plants dan vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D),  
 231 cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)



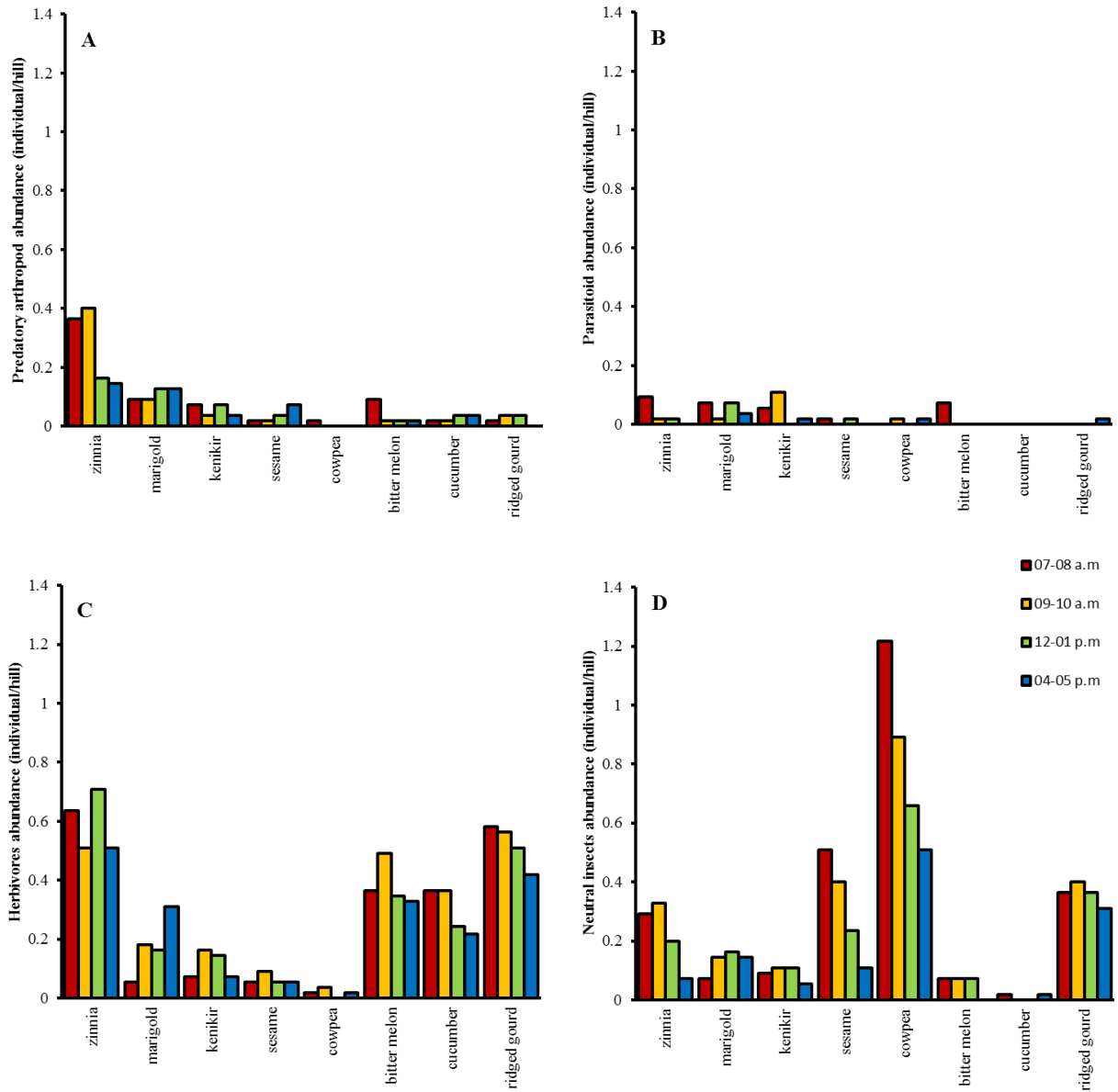
287 **Figure 3.** Arthropod abundance inhabiting non-crop plants and vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea  
288 (E), bitter melon (F), cucumber (G), and ridged gourd (H)  
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**Figure 4.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables

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**Figure 5.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables at 07-08 a.m, 09-10 a.m, 12-01 p.m, 04-05 p.m

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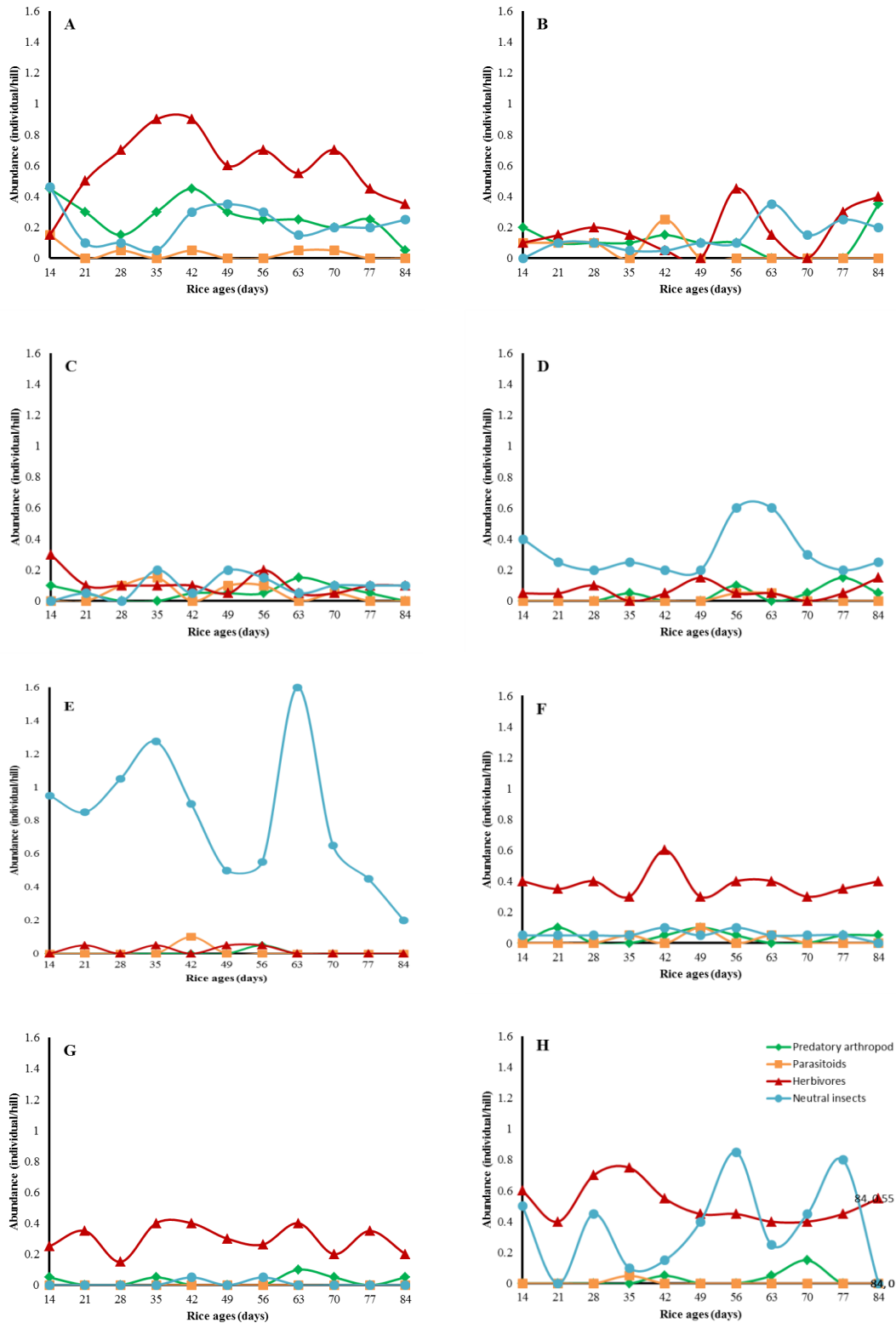


Figure 6. Abundance arthropod inhabiting non-crop plants and vegetables in the period 14-84 days after transplanting: zinnia (A), marigold (B), kenikir (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)

424 **Discussion**

425 *Cosmophasis* sp., *T. mandibulata*, *O. javanus*, *Oxyopes* sp., *O. transversa*, *M. sexmaculatus*, *Pantala* sp., and *O.*  
426 *planiceps* were paddy pest insect predators in this study. In line with Tahir et al. (2009) *T. mandibulata* are predators of  
427 Homoptera and Lepidoptera on paddy. *O. javanus* and *Oxyopes* spp. can attack, among others, *Sogetella furcilera*, and  
428 *Scripophaga innotata* on paddy in Pakistan (Tahir et al. 2009). *M. sexmaculatus* and Coccinellidae are generalist predators  
429 (Karindah, 2011) able to prey on *N. virescens* and *N. lugens* on paddy in India (Shanker et al. 2018).

430 At zinnia and bitter melon, the abundance of predators is higher than the abundance in 6 other plant species. Zinnia is  
431 preferred because of its longer blossoming period and Wahocho et al. (2016) stated that Zinnia sp. Can bloom for 23,67  
432 days (Wahocho et al. 2016). Bitter melon has a yellow color preferred by the predatory arthropods compared to other  
433 colors. In line with the opinion of Rocha-Filho and Rinaldi (2011), arthropods prefer yellow flowers rather than white and  
434 pink flowers. In addition, in this study the abundance of herbivores in zinnia and bitter melons can affect the high  
435 abundance of these generalist predators. This phenomenon is common because generalist predators look for prey in the  
436 habitat (Karenina et al. 2019).

437 In addition to predators, zinnia and bitter melon are also the most chosen parasitoids for their habitat. The shape of  
438 rosette flower of zinnia sp. and bitter melon is highly attracted to predators and parasitoids. In line with the opinion of  
439 Jennings et al. (2017), the rosette-shaped flowers are visited by arthropods longer. Pollen and nectar existing in non-crop  
440 plants flowers and vegetables can also increase the attractiveness of flowers for niche arthropods, such as spiders (Eggs &  
441 Sanders, 2013) and parasitoids (Foti et al. 2017).

442 The most dominant herbivores are found in non-crop plants, zinnia, marigolds, and *cosmos caudatus*, and in  
443 vegetables, bitter melons, cucumber, and ridged gourd. These dominant herbivores include *Valanga nigricornis*, *Acrida*  
444 *turrata*, and *Oxya chinensis* which are grasshoppers and not key pests, but the presence of herbivores in these plants is  
445 useful for prey generalist predators which are natural enemies of key pests in paddy. In herbivores of non-crop plants and  
446 vegetables there are no key pests that attack paddy, such as *Nilaparvata lugens*, *Nephotettix virescens*, *Sogatella furcifera*  
447 and *Leptocorisa acuta*. Therefore, the presence of non-crop plants and vegetables does not function as an alternative  
448 habitat for key pests but acts as a habitat and niche for natural enemies and herbivores which are not key pests, but the  
449 herbivores have an important role as an alternative prey for predatory arthropods. Settle et al. (1996) pointed out that  
450 herbivores which are not key pests are also important in the presence of agroecosystems for prey generalist predators and  
451 so are neutral insects that are important as stocks of predator prey if the key pests are not found in paddy.

452 In this study, *O. transversa* is an ant classified as a neutral insect commonly found in sesame and cowpea because this  
453 group of ants is associated with the cucumber which attacks both plants. The presence of ants (Formicidae) in sesame and  
454 cowpea can reduce the arrival of parasitoids and predators in these plants. The presence of the ants reduces the comfort of  
455 parasitoids and predatory arthropods to settle and look for a host or prey. In line with the results of the research conducted  
456 by Sanders et al. (2011) ants can reduce spider activity in suppressing and reducing herbivores populations. Species  
457 diversity and spider abundance decrease significantly when the habitat is inhabited by ants (Stefani et al. 2015).  
458 Consequently, sesame and cowpea are less suitable to be used as refugia functioning to conserve parasitoids and predatory  
459 arthropods which are natural enemies of paddy pests.

460 The highest parasitoid abundance is found in marigolds which are commonly found in the morning. The marigold is  
461 preferred because it has a longer availability of pollen and nectar. This is because it is able to bloom for 48.47 days  
462 (Gobade et al. 2017). The marigold yellow color is an attraction for parasitoid to perch and suck the nectar. The shape and  
463 color of marigolds are most ideal for parasitoids looking for food (Souza et al. 2019). Several types of parasitoid  
464 Brassicaceae pests found inhabiting marigolds, for example the Family Braconidae, Ichneumonidae, Eulophidae, and  
465 Pteromalidae (Velcheva et al. 2017) and Tachinidae (Razmi et al. 201).

466 To sum up, the non-crop plants to be recommended for the conservation of parasitoids and predators of paddy pests are  
467 zinnia and marigolds, while the recommended crop is bitter melon. However, for increasing land productivity while at the  
468 same time preserving predators and parasitoids, planting bitter melon in paddy fields is more profitable than planting  
469 zinnia and marigolds.

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## 2. Bukti konfirmasi review pertama dan hasil revisi pertama

The image displays two screenshots of a Gmail inbox, illustrating the first review and the first revision of a manuscript.

**Top Screenshot: Review Email**

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- Content:**
  - Greeting: Siti Herlinda:
  - Text: "We have reached a decision regarding your submission to **Biodiversitas** Journal of Biological Diversity, "Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swampy lowlands of South Sumatra".
  - Decision: "Our decision is: Revisions Required"
  - Signature: Smujo Editors, [editors@smujo.id](mailto:editors@smujo.id)
  - Reviewer A's comment: "This manuscript presents good information for the agriculture sector, therefore I recommend accepting this ms for publication after revision. However, there are some suggestions and comments to the authors. I placed them in the text. The important thing is please add how to count the values presented in Figs. 2-6 and Table 1-3 in the data analysis."

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  - Greeting: Dear Editor
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# Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swamps of South Sumatra

**Abstract.** Local farmers in freshwater swamps of South Sumatra traditionally plant adaptive flowering vegetables surrounding paddy fields and let wild flowering plants or non-crop plants grow on the embankment. This research aimed to determine the species of non-crop plants and adaptive vegetables surrounding the freshwater swamp paddy fields as habitats and niches of arthropods. This study used four species of flowering non-crop plants (*Zinnia* sp., *Tagetes erecta*, *Cosmos caudatus*, *Sesamum indicum*) and four species of vegetables (*Vigna unguiculata*, *Momordica charantia*, *Cucumis sativus*, *Luffa acutangula*) planted around the paddy fields. While the arthropods were collected using sweep nets. There were 24 species of predatory arthropods, three species of parasitoids, 17 species of herbivores, and nine species of neutral insects found in the non-crop plants and vegetables. The non-crop plant and vegetable species that were the most chosen by the predatory arthropods were *Zinnia* sp. and *M. charantia*, respectively. Species of the non-crop plants and vegetables chosen by the parasitoids were *T. erecta* and *M. charantia*, respectively. Those non-crop plants and adaptive vegetables were also the most chosen plants by the predatory arthropods for their habitats and niches. Therefore, for the conservation of natural enemies, it is better to use *Zinnia* sp., *T. erecta*, and *M. charantia*.

**Key words:** herbivores; neutral insects; parasitoids; predatory arthropods; predatory insects

**Abbreviations** (if any): -

**Running title:** Arthropods inhabiting flowering non-crop plants

## INTRODUCTION

Freshwater swamps are wetlands saturated with water, either throughout the year or seasonally due to the influence of river water or rain. In Indonesia, freshwater swamps reach 9.2 Mha spreading across Sumatra, Kalimantan, and Papua (Mulyani and Sarwani, 2013). Freshwater swamps have three land typologies, namely shallow, middle, and deep, generally cultivated as adaptive plants (Siaga et al. 2019). All of the three land typologies are generally planted with paddy (Herlinda et al. 2018; Lakitan et al. 2018; Prabawati et al. 2019). On paddy fields planted in the shallow and middle swampy of lowlands, they are generally also planted with adaptive vegetables, such as chili (Johari et al. 2014, 2016), long beans, bitter melon, ridge gourd, eggplant, and cucumber (Siaga et al. 2019). On the embankments not planted with adaptive vegetables, they are generally not weeded, but wild plants (non-crop plants) can still grow there (Herlinda et al. 2019; Karenina et al. 2019). In addition, the local farmers are not accustomed to applying synthetic pesticides (Herlinda et al. 2018).

Unnoticed by the farmers, the wild vegetables and plants can act as habitats and arthropod niches both as natural enemies and insect pests (Hassan et al. 2016; McCabe et al. 2017). Apart from being alternative habitats and niches for natural enemies, these wild vegetables and plants also act as niches due to providers of nectar and pollen (Karenina et al. 2019). The nectar and pollen can increase the longevity, fecundity, and fitness of adult natural enemies (Desai et al. 2017; Foti et al. 2017).

Some previous researches on the arthropods inhabiting plants have been done. According to Desai et al. (2017), in some species of flowering non-crop plants, for example, *Zinnia* sp., spiders (*Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp.) are found settling. Furthermore, *Tagetes erecta* is inhabited by *Oxyopes javanus*, *Coccinella septumpunctata*, *Syrphus* spp., *Geocoris* spp., *Apis dorsata*, *A. mellifera*, and *Vanessa cardui* (Ganai et al. 2017). The natural enemies of predatory arthropods, namely Pentatomidae and Mantidae and parasitoids from Eulophidae, Tachinidae, and Ichneumonidae are found in non-crop plants (*Antigonon leptopus*, *Turnera subulata*, and *Ageratum* sp.) (Saleh and Siregar 2017).

Paddy of freshwater swamps surrounded by vegetables, such as *V. sinensis*, *C. sativus*, *M. charantia*, and *L. acutangula* has an abundance and variety of arthropod predator species more than that not surrounded by the four vegetable species mentioned above (Karenina et al. 2019). Consequently, it is necessary to find out the species of non-crop plants and

adaptive vegetables as habitats and niches of arthropods, especially predatory arthropods and parasitoids as natural enemies of paddy pest insects. The study aimed to determine the species of non-crop plants and adaptive vegetables surrounding the freshwater swamp paddy fields as habitats and niches of arthropods.

## MATERIALS AND METHODS

The study was carried out in the freshwater swamp paddy fields of Pelabuhan Dalam Village in Pemulutan Subdistrict of Ogan Ilir District of South Sumatra Province from May to November 2018. The identification of arthropod species was conducted from December to March 2019 by Dr. Chandra Irsan from Universitas Sriwijaya. The location of the study was carried out in a freshwater swamp paddy center surrounded by monoculture paddy on an area of  $\pm$  800 ha. In this study, four species of non-crop plants were planted in paddy fields surrounding 1 ha of freshwater swamp paddy and 1 ha of the other paddy plots was surrounded by four species of local vegetables planted in the embankment of paddy fields.

### Growing Non-crop plants and vegetables

The planting of non-crop plants and vegetables was carried out 30 days before planting paddy so that when it reached 14 days after transplanting (DAT), the non-crop plants and vegetables began to bloom. There were two paddy plots of 1 ha each. The first plot was surrounded by four species of non-crop plants: zinnia (*Zinnia* sp.), marigold (*Tagetes erecta*), kenikir (*Cosmos caudatus*), and sesame (*Sesamum indicum*) planted on four sides of the embankment. The second plot was surrounded by four species of vegetables: cowpea (*Vigna unguiculata*), bitter melon (*Momordica charantia*), cucumber (*Cucumis sativus*), and ridge gourd (*Luffa acutangula*). The spacing between planting holes was 30 cm for long beans, 60 cm for bitter melons, 40 cm for cucumbers, and 30 cm for ridge gourd. As for non-crop plants, the spacing between planting holes was 15 cm.

### Paddy planting

The stages of paddy planting started from tillage, seed treatment, nursery, transplanting, and fertilizing using manure and liquid compost extract. Land preparation and processing began with clearing weeds and then soil treatment while applying manure at a dose of 1 ton.ha<sup>-1</sup> and liquid compost extract at a dose of 2 L.ha<sup>-1</sup>. Liquid compost extract was made following the method of Suwandi et al. (2012) enriched with *Trichoderma virens*. The paddy seeds used *mekongga* variety, which was already treated using compost extract when ripening the seeds for 1 x 24 hours. After that, the seeds were sown and covered with a banana leaf on a plastic tray (size 36 cm x 27 cm x 4.5 cm) for 14 days. The 14-day-old paddy seedlings were transplanted into the fields with the 2:1 *legowo* row system with a planting space of 50 cm x 25 cm x 12.5 cm.

### Observation of arthropod inhabiting non-crop plants and vegetables

The observation of arthropod inhabiting non-crop plants and vegetables surrounding the paddy was conducted once a week, starting when the paddy reached 14 to 84 days after transplanting. This observation was a continuation of the research of Karenina et al. (2019) who sampled by taking five flowers for each species of non-crop plants and vegetables, while in this study the sampling was carried out by observing directly and documenting arthropods that perched on non-crop plants flowers or leaves and vegetables at 07–08 a.m., 09–10 a.m., 12–01 p.m., and 04–05 p.m. Direct observations were conducted on five flowers for each species of non-crop plants and vegetables. The observations were made by recording and documenting the arthropods that perched. The inhabiting arthropods were identified based on their morphological characteristics. Identification of spiders referred to Barrion and Litsinger (1995) and identifying insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

### Data analysis

Arthropod composition and abundance data on non-crop plants and vegetables were analyzed descriptively and presented in tables and graphs. The arthropod abundance data were also further grouped by guild, namely predator (spiders and predatory insects), parasitoids, herbivores, and neutral insects to be displayed in graphical form. Data presented in Tabel 1–4 were counted from the mean of arthropod abundance from five flowers for each species of the plants during 11 observations (11 weeks). Data of Figure 2 were obtained from proportion of the total abundance of each guild and the total abundance of all guilds. The mean of arthropod family abundance from each plant was presented in Figure 3. Data of Figure 4 were obtained from the mean of abundance from each guild (predatory arthropod, parasitoids, herbivores, and neutral insects). Data presented in Figure 5 were counted from the mean of abundance from each guild sampled at 07–08 a.m., 09–10 a.m., 12–01 p.m., 04–05 p.m. Data for Figure 6 were obtained from the mean of arthropod abundance from each observation since 14 until 84 days.

## RESULTS AND DISCUSSION

**Arthropod abundance inhabiting non-crop plants and vegetables**

Dominant arthropods inhabiting non-crop plants and vegetables were *Cosmophasis* sp., *Tetragnatha mandibulata*, *Oxyopes javanus*, *Oxyopes* sp., *Odontoponera transversa*, *Menochilus sexmaculatus*, *Pantala* sp., and *Odontomantis planiceps* (Figure 1). The most dominant species of predatory arthropods at non-crop plants were *Odontomantis planiceps*, while at the vegetables, it was Coccinellidae (unknown species). During one paddy planting season, 24 species of predatory arthropods (spiders and predatory insects) were found inhabiting non-crop plants and vegetables. The species of non-crop plants most chosen by the predatory arthropods was zinnia (0.271 individuals/hill), while the adaptive vegetable chosen was bitter melon (0.039 individuals/hill) (Table 1). The number of species of predatory arthropods in zinnia and bitter melons was the largest, comprising 15 species and 6 species, respectively.

**Table 1.** Predatory arthropod abundance inhabiting non-crop plants and vegetables

| Species                            | Predatory arthropod abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|------------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                    | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |
| 25. <i>Pardosa</i> sp.             | 0.009   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 26. <i>Argiope</i> sp.             | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 27. <i>Tetragnatha virescens</i>   | 0   | 0        | 0       | 0      | 0.005  | 0            | 0        | 0            |
| 28. <i>Tetragnatha mandibulata</i> | 0.023   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 29. Linyphiidae (unknown sp.)      | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 30. <i>Oxyopes matiensis</i>       | 0.032   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |
| 31. <i>Oxyopes javanus</i>         | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 32. Thomisidae (unknown)           | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |
| 33. <i>Cosmophasis</i> sp.         | 0.045   | 0.018    | 0       | 0.014  | 0      | 0            | 0        | 0            |
| 34. Salticidae (unknown sp.)       | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 35. <i>Menochilus sexmaculatus</i> | 0.014   | 0.005    | 0       | 0.005  | 0      | 0.014        | 0.009    | 0.009        |
| 36. Coccinellidae (unknown sp.)    | 0.005   | 0.009    | 0       | 0      | 0      | 0.005        | 0.018    | 0            |
| 37. <i>Formicomus</i> sp.          | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 38. <i>Paederus fuscipes</i>       | 0.005   | 0        | 0       | 0      | 0      | 0.005        | 0        | 0            |
| 39. Chloropidae (unknown sp.)      | 0   | 0.032    | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 40. <i>Chrysosoma leucopogon</i>   | 0.018   | 0.005    | 0       | 0      | 0      | 0.005        | 0        | 0            |
| 41. <i>Eristalinus</i> sp.         | 0.005   | 0        | 0       | 0      | 0      | 0.005        | 0        | 0            |
| 42. <i>Eristalis</i> sp.           | 0   | 0.009    | 0.018   | 0      | 0      | 0.005        | 0        | 0            |
| 43. <i>Ropalidia marginata</i>     | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0.005        |
| 44. <i>Odontomantis planiceps</i>  | 0.068   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |
| 45. <i>Archimantis</i> sp.         | 0   | 0        | 0.014   | 0      | 0      | 0            | 0        | 0            |
| 46. Mantidae (unknown sp.)         | 0.014   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |
| 47. <i>Pantala flavescens</i>      | 0.018   | 0.027    | 0       | 0.005  | 0      | 0            | 0        | 0.005        |
| 48. <i>Ictinogomphus</i> sp.       | 0   | 0        | 0       | 0      | 0      | 0            | 0        | 0.005        |
| Total of abundance                 | 0.271   | 0.11     | 0.057   | 0.039  | 0.005  | 0.039        | 0.027    | 0.024        |
| Total of species                   | 15  | 8        | 7       | 6      | 1      | 6            | 2        | 4            |

**Table 2.** Parasitoids abundance inhabiting non-crop plants and vegetables

| Species                        | Parasitoids abundance inhabiting non-crop plants dan vegetables (individual/hill) |          |         |        |        |              |          |              |
|--------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |
| 4. <i>Cryptochetum iceryae</i> | 0.009   | 0.014    | 0.014   | 0.005  | 0.005  | 0            | 0        | 0            |
| 5. Sarcophagidae (unknown sp.) | 0.009   | 0.018    | 0.009   | 0.005  | 0.005  | 0.014        | 0        | 0            |
| 6. <i>Blondelia nigripes</i>   | 0.014   | 0.018    | 0.023   | 0      | 0      | 0.005        | 0        | 0.005        |
| Total of abundance             | 0.032   | 0.05     | 0.046   | 0.01   | 0.01   | 0.019        | 0        | 0.005        |
| Total of species               | 3   | 3        | 3       | 2      | 2      | 2            | 0        | 1            |

The parasitoid species found in non-crop plants were a large number of *Blondelia nigripes*, while those found in vegetables were *Sarcophagidae* (Table 2). During the paddy planting season, there were found 3 species of parasitoid families inhabiting the non-crop plants and vegetables. The highest parasitoid abundance in non-crop plants was found in zinnia and the highest parasitoid abundance in vegetables was found in bitter melons.

Species of herbivores or phytophagous species found in non-crop plants were *Pelopidas thrax*, while the species most commonly found in vegetables was *Aulacophora frontalis* (Table 3). During the paddy planting season, 17 species of herbivores were found inhabiting non-crop plants and vegetables. The highest abundance of herbivores in non-crop plants was found in zinnia and the highest abundance of herbivores in vegetables was found in the ridged gourd.

The species of neutral insects found in non-crop plants and vegetables was *Odontoponera transversa*. During the paddy planting season, nine species of neutral insects were found inhabiting non-crop plants and vegetables (Table 4). The highest abundance of neutral insects in non-crop plants was found in sesame, and the highest abundance of neutral insects in vegetables was found in cowpeas.

**Table 3.** Herbivore abundance inhabiting non-crop plants and vegetables

| Species                           | Herbivore abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|-----------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                   | zinnia  | marigold | kenikir | sesame | cowpea | Bitter melon | cucumber | Ridged gourd |
| 18. <i>Chrysolina coeruleans</i>  | 0.018   | 0        | 0.005   | 0.005  | 0      | 0.014        | 0.009    | 0.009        |
| 19. <i>Aulacophora frontalis</i>  | 0   | 0.005    | 0       | 0      | 0      | 0.073        | 0.014    | 0.482        |
| 20. <i>Aulacophora indica</i>     | 0   | 0        | 0       | 0      | 0      | 0.005        | 0.151    | 0            |
| 21. <i>Charidotella</i> sp.       | 0   | 0        | 0       | 0      | 0      | 0            | 0.005    | 0            |
| 22. <i>Epilachna dodecastigma</i> | 0   | 0        | 0       | 0      | 0      | 0.059        | 0.005    | 0.023        |
| 23. <i>Cletus trigonus</i>        | 0.036   | 0.009    | 0.005   | 0      | 0      | 0.032        | 0        | 0            |
| 24. <i>Amata nigriceps</i>        | 0.018   | 0.045    | 0       | 0      | 0.018  | 0.050        | 0.009    | 0            |
| 25. <i>Petrophora</i> sp.         | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 26. <i>Perizoma</i> sp.           | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |
| 27. <i>Pelopidas thrax</i>        | 0.291   | 0.041    | 0.036   | 0      | 0      | 0.077        | 0.005    | 0            |
| 28. <i>Spodoptera</i> sp.         | 0.009   | 0        | 0       | 0      | 0      | 0.009        | 0        | 0            |
| 29. <i>Eurema blanda</i>          | 0.009   | 0        | 0.023   | 0      | 0      | 0.014        | 0        | 0            |
| 30. <i>Aporia</i> sp.             | 0.009   | 0.009    | 0.005   | 0      | 0      | 0            | 0        | 0            |
| 31. <i>Valanga nigricornis</i>    | 0.123   | 0.041    | 0.032   | 0.045  | 0      | 0.050        | 0.100    | 0            |
| 32. <i>Acrida turrita</i>         | 0.032   | 0.023    | 0.005   | 0.014  | 0      | 0            | 0        | 0.005        |
| 33. <i>Oxya chinensis</i>         | 0.041   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 34. <i>Tetrix subulata</i>        | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| Total of abundance                | 0.591   | 0.178    | 0.116   | 0.064  | 0.018  | 0.383        | 0.298    | 0.519        |
| Total of species                  | 11  | 8        | 8       | 3      | 1      | 10           | 8        | 4            |

**Table 4.** Neutral insect abundance inhabiting non-crop plants and vegetables

| Species                            | Neutral insect abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|------------------------------------|--|----------|---------|--------|--------|--------------|----------|--------------|
|                                    | zinnia   | marigold | kenikir | sesame | cowpea | bitter melon | cucumber | ridged gourd |
| 10. Chironomidae (unknown sp.)     | 0.005  | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 11. <i>Rainieria antennaepes</i>   | 0.036  | 0.014    | 0.023   | 0.009  | 0.005  | 0            | 0.005    | 0.005        |
| 12. <i>Neomyia cornicina</i>       | 0.009  | 0.005    | 0.018   | 0.027  | 0      | 0            | 0        | 0            |
| 13. <i>Chloromyia farmosa</i>      | 0.005  | 0        | 0.014   | 0      | 0      | 0            | 0        | 0.005        |
| 14. <i>Hermetia</i> sp.            | 0.005  | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| 15. <i>Tipula maxima</i>           | 0.045  | 0.009    | 0.014   | 0.005  | 0      | 0            | 0.005    | 0            |
| 16. <i>Trigona</i> sp.             | 0.118  | 0.082    | 0.023   | 0      | 0      | 0.055        | 0        | 0.005        |
| 17. <i>Apis cerana</i>             | 0  | 0.014    | 0       | 0      | 0      | 0            | 0        | 0            |
| 18. <i>Odontoponera transversa</i> | 0  | 0.009    | 0       | 0.273  | 0.815  | 0            | 0        | 0.345        |
| Total of abundance                 | 0.223  | 0.133    | 0.092   | 0.314  | 0.82   | 0.055        | 0.01     | 0.36         |
| Total of species                   | 7  | 6        | 5       | 4      | 2      | 1            | 2        | 4            |

#### Arthropod community and guilds inhabiting non-crop plants and vegetables

The arthropod community inhabiting non-crop plants and vegetables varied between plant species. Guild of herbivores was predominantly found in all of the non-crop plants and vegetable species, except sesame and cowpea (Figure 2). The sesame and cowpea were dominated by a neutral insect community, primarily *Odontoponera transversa*.

The arthropod community inhabiting non-crop plants and vegetables varied between plant species (Figure 3). They were dominated by four families, namely Hesperidae, Apidae, Formicidae, and Chrysomelidae. Arthropods inhabiting *Zinnia* sp. and *C. caudatus* were dominated by the Hesperidae; the marigolds were dominated by the Apidae; the sesame and cowpea were dominated by Formicidae; and the bitter melon, cucumber, and ridge gourd were dominated by Chrysomelidae.

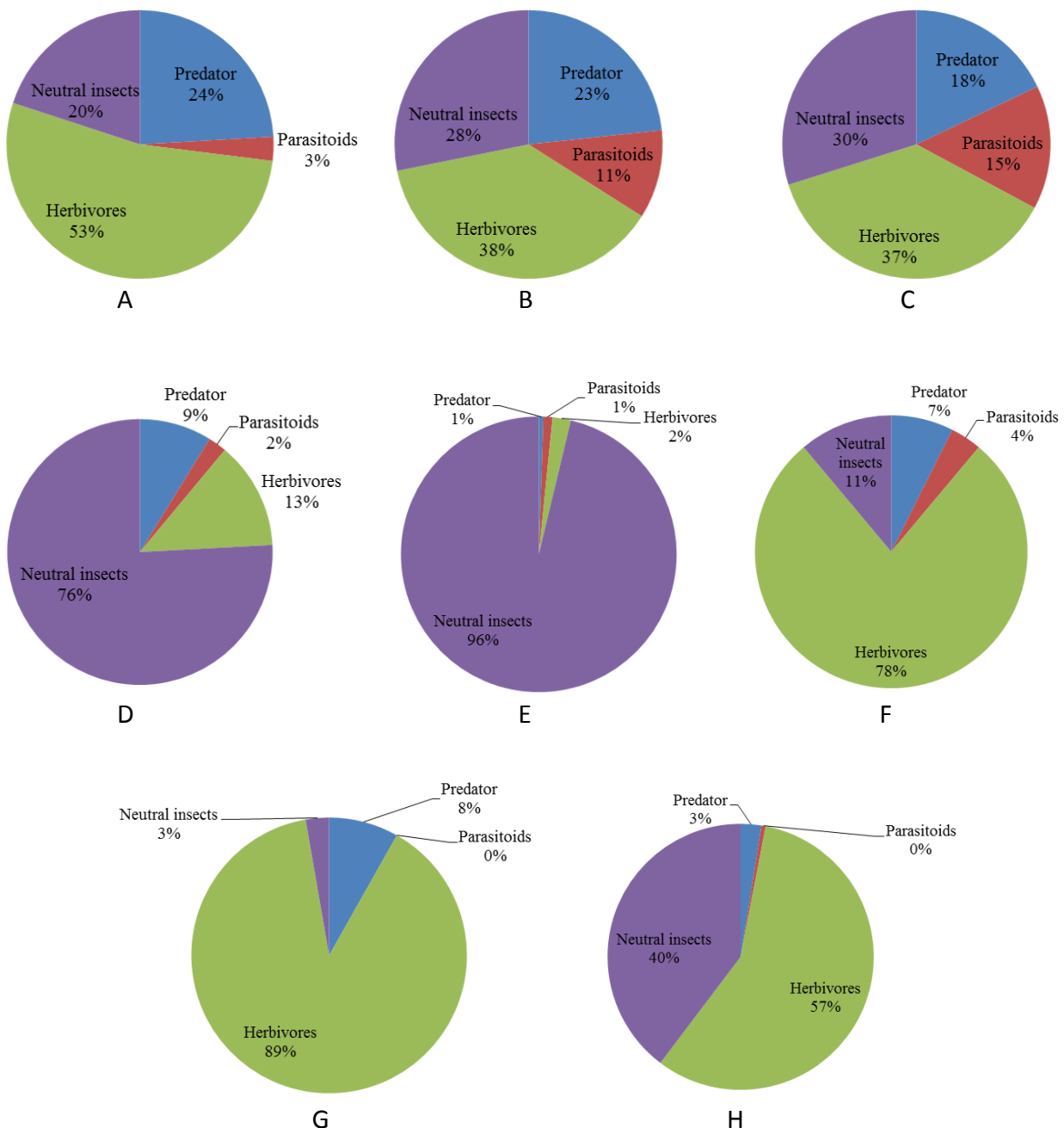
The highest abundance predators inhabiting non-crop plants was found in zinnia. The highest abundance of predators inhabiting zinnia was followed by that of herbivores and neutral insects (Figure 4). There was a link among the abundance of predators, herbivores, and neutral insects inhabiting the plants. The highest abundance of predators inhabiting vegetables was found in bitter melons, followed by parasitoids and herbivores. The high abundance of predators in bitter melons was not followed by that of neutral insects. The highest abundance of neutral insects in vegetables was found in cowpeas.



**Figure 1.** Dominant arthropod species inhabiting non-crop plants and vegetables: *Cosmophasis* sp. (A), *Tetragnatha mandibulata* (B), *Oxyopes javanus* (C), *Oxyopes* sp. (D), *Odontoponera transversa* (E), *Menochilus sexmaculatus* (F), *Pantala* sp. (G), *Odontomantis planiceps* (H), *Pelopidas* sp. (I), *Amata nigripes* (J), *Aulacophora indica* (K), *Valanga nigricornis* (L), *A. frontalis* (M), *Tipula* sp. (N), *Trigona* sp. (O), and *Rainieria antennaepe* (P)

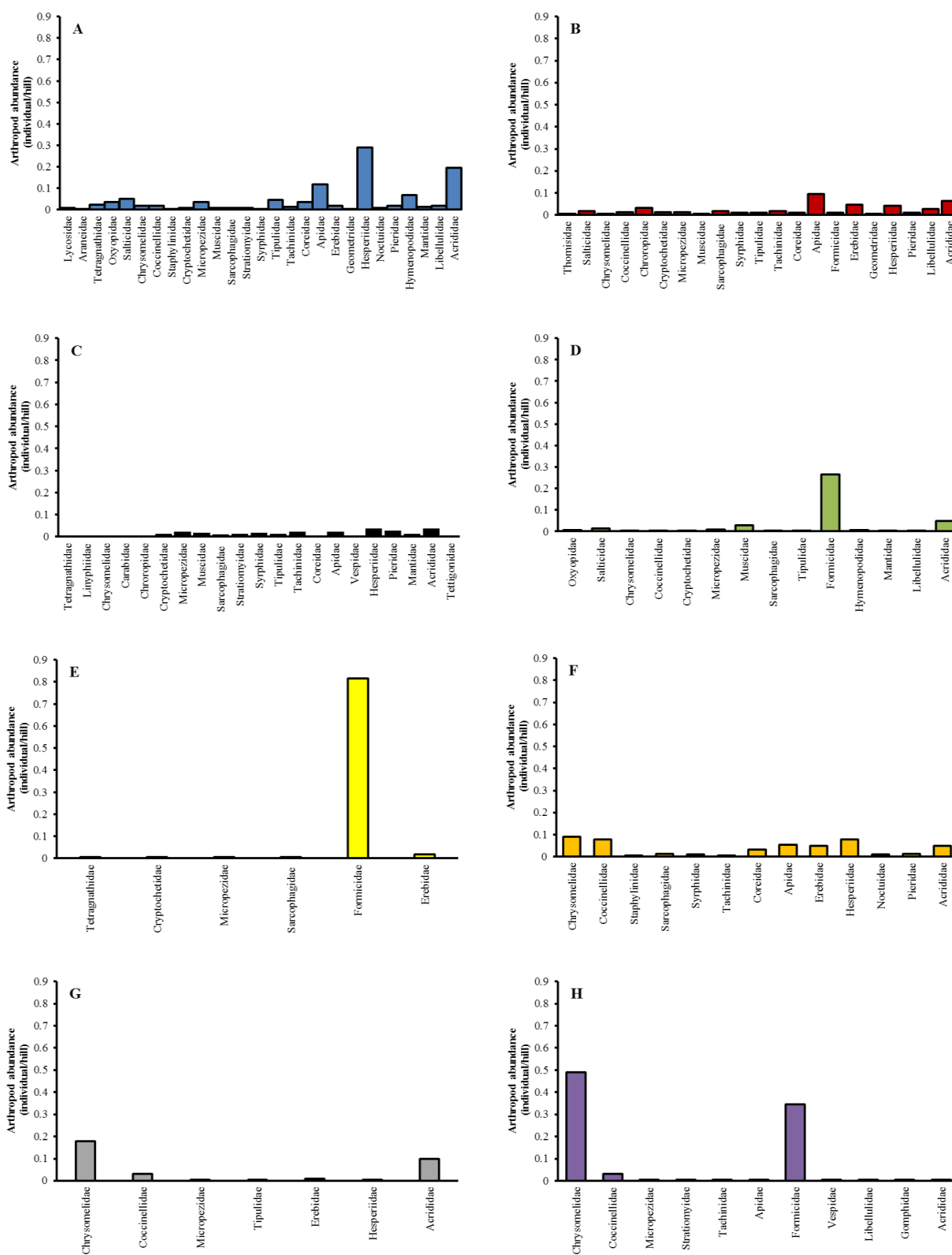
The abundance of four community guilds of arthropods inhabiting non-crop plants and vegetables had a different tendency (Figure 5). Predators visited non-crop plants and vegetables all day from morning to evening. Predators tended visit *Zinnia* in the afternoon and evening, *C. caudatus* in the morning and evening, cowpea and bitter melon in the morning, and ridge gourd in the afternoon and evening. Parasitoids generally visited non-crop plants and vegetables in the morning, for example zinnia, marigolds, sesame, and bitter melons were visited at 07–08 a.m., while *C. caudatus* and cowpea were mostly visited at 09–10 a.m. However, ridge gourd was visited by parasitoids in the afternoon at 04-05 p.m. Among those flowers, the marigolds were the most chosen by the parasitoids. Herbivores visited non-crop plants and vegetables throughout the day, while many neutral insects visited non-crop plants and vegetables in the morning.

The abundance of guild arthropods found in non-crop plants and vegetables fluctuated during one paddy planting season. When paddy was initially planted, the abundance of arthropods found in non-crop plants and vegetables tended to be lower and continued to increase and reached a peak in the ripe phase of milk (56-70 DAT), nearing the harvest it tended to decline. During one planting season, the abundance of herbivores in zinnia, bitter melons, cucumber, and ridge gourd was always higher compared to other guilds, whereas in sesame and cowpeas, the abundance of neutral insects was always high (Figure 6). The abundance of predators and herbivores was highest in zinnia., The abundance of predators tended to be affected by the fluctuations of herbivores' abundance.

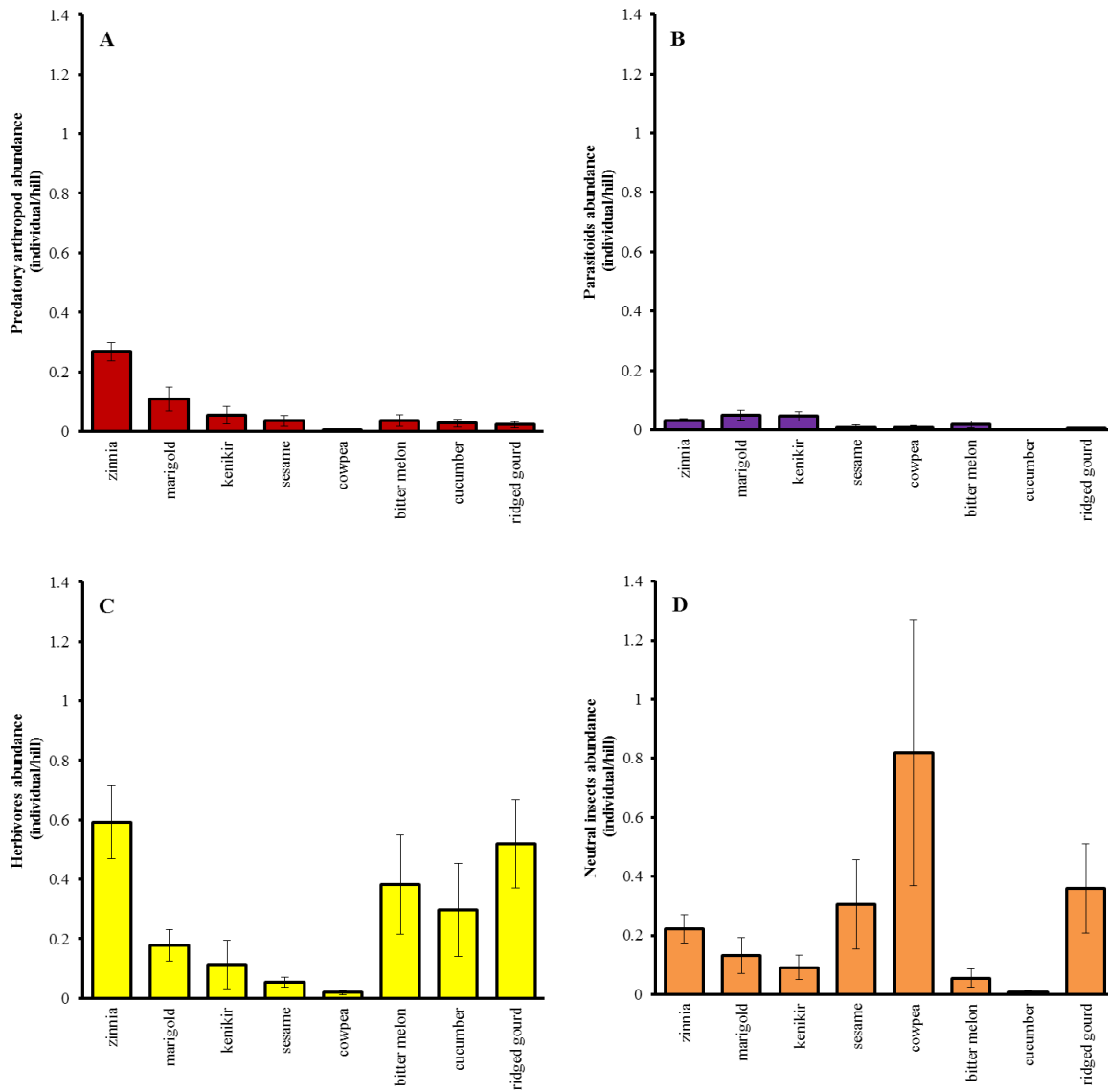




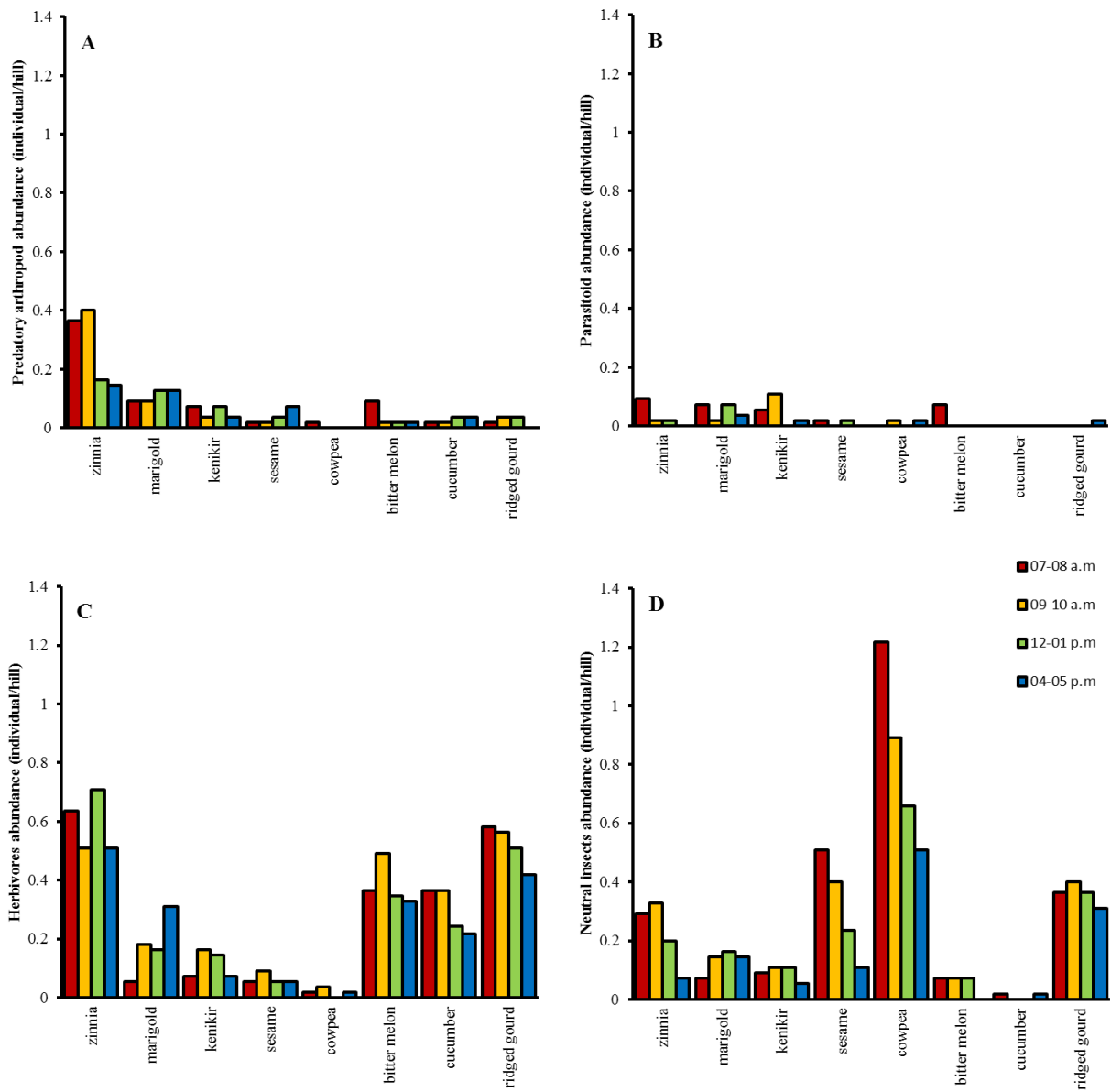
**Figure 2.** Proportion of arthropod guilds inhabiting non-crop plants dan vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)



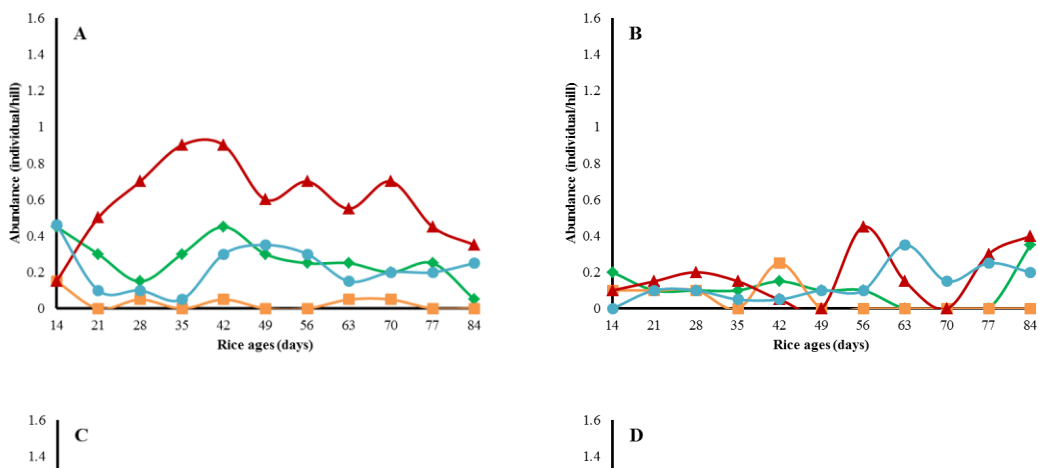
**Figure 3.** The mean abundance of arthropod family inhabiting non-crop plants and vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridge gourd (H)



**Figure 4.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables



**Figure 5.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables at 07-08 a.m, 09-10 a.m, 12-01 p.m, 04-05 p.m



**Figure 6.** Abundance arthropod inhabiting non-crop plants and vegetables in the period 14-84 days after transplanting: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)

### Discussion

*Cosmophasis* sp., *T. mandibulata*, *O. javanus*, *Oxyopes* sp., *O. transversa*, *M. sexmaculatus*, *Pantala* sp., and *O. planiceps* were paddy pest insect predators in this study. In line with Tahir et al. (2009), *T. mandibulata* are predators of

Homoptera and Lepidoptera on paddy. *O. javanus* and *Oxyopes* spp. can attack, among others, *Sogetella furcilera*, and *Scripophaga innotata* on paddy in Pakistan (Tahir et al. 2009). *M. sexmaculatus* and Coccinellidae are generalist predators (Karindah, 2011) able to prey on *N. virescens* and *N. lugens* on paddy in India (Shanker et al. 2018).

At zinnia and bitter melon, the abundance of predators is higher than the abundance in six other plant species. Zinnia is preferred because of its longer blossoming period, and Wahocho et al. (2016) stated that *Zinnia* sp. can bloom for 23,67 days (Wahocho et al. 2016). Bitter melon has a yellow color preferred by the predatory arthropods compared to other colors. In line with the study of Rocha-Filho and Rinaldi (2011), arthropods prefer yellow flowers rather than white and pink flowers. In this study, the abundance of herbivores in zinnia and bitter melons can affect the abundance of these generalist predators. This phenomenon is common because generalist predators look for prey (Karenina et al. 2019). Zinnia and bitter melon are also the most chosen parasitoids for their habitat. The shape of the rosette flower of *Zinnia* sp. and bitter melon is highly attracted to predators and parasitoids. In line with the opinion of Jennings et al. (2017), the rosette-shaped flowers are visited by arthropods longer. Pollen and nectar existing in non-crop plants flowers and vegetables can also increase the attractiveness of flowers for niche arthropods, such as spiders (Eggs and Sanders 2013) and parasitoids (Foti et al. 2017).

The guild of herbivores dominated in all of plant species except sesame and cowpea. The species are *Valanga nigricornis*, *Acrida turrata*, and *Oxya chinensis*, which are grasshoppers and not key pests. However, the presence of herbivores in these plants is useful for prey generalist predators which are natural enemies of key pests in paddy. In herbivores of non-crop plants and vegetables, there are no key pests such as *Nilaparvata lugens*, *Nephotettix virescens*, *Sogetella furcifera*, and *Leptocorisa acuta* that attack paddy. Therefore, the presence of non-crop plants and vegetables does not function as an alternative habitat for key pests but acts as a habitat and niche for natural enemies and herbivores, which are not key pests. Still, the herbivores have an important role as alternative prey for predatory arthropods. Settle et al. (1996) pointed out that herbivores, which are not key pests, are also important in the presence of agroecosystems for prey generalist predators, and so are neutral insects that are important as stocks of predator-prey if the key pests are not found in paddy.

In this study, *O. transversa* is an ant classified as a neutral insect commonly found in sesame and cowpea because this group of ants is associated with the cucumber, which attacks both plants. The presence of ants (Formicidae) in sesame and cowpea can reduce the arrival of parasitoids and predators in these plants. The presence of the ants reduces the comfort of parasitoids and predatory arthropods to settle and look for a host or prey. In line with the results of the research conducted by Sanders et al. (2011), ants can reduce spider activity in suppressing and reducing herbivores populations. Species diversity and spider abundance decrease significantly when the habitat is inhabited by ants (Stefani et al. 2015). Consequently, sesame and cowpea are less suitable to be used as refugia functioning to conserve parasitoids and predatory arthropods, which are natural enemies of paddy pests.

The highest parasitoid abundance is found in marigolds which are commonly found in the morning. The marigold is preferred because it has a longer availability of pollen and nectar. This is because it is able to bloom for 48.47 days (Gobade et al. 2017). The marigold yellow color is an attraction for parasitoid to perch and suck the nectar. The shape and color of marigolds are the most ideal for parasitoids looking for food (Souza et al. 2019). Several types of parasitoid Brassicaceae pests found inhabiting marigolds, for example, the Family Braconidae, Ichneumonidae, Eulophidae, and Pteromalidae (Velcheva et al. 2017) and Tachinidae (Razmi et al. 201).

To sum up, the non-crop plants to be recommended for the conservation of parasitoids and predators of paddy pests are zinnia and marigolds, while the recommended crop is bitter melon. However, for increasing land productivity while at the same time preserving predators and parasitoids, planting bitter melon in paddy fields is more profitable than planting zinnia and marigolds.

## ACKNOWLEDGEMENTS

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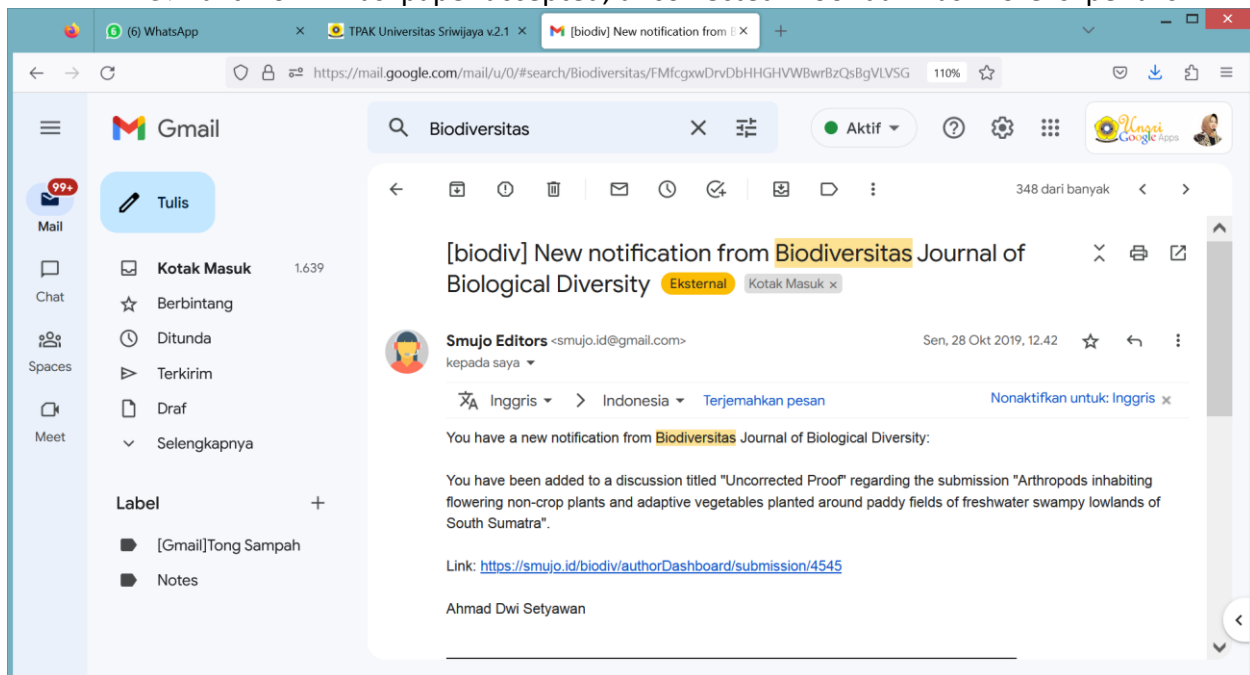
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## 3. Bukti konfirmasi paper accepted, uncorrected Proof dan hasil koreksi penulis



## Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swamps of South Sumatra, Indonesia

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**Abstract.** Herlinda S, Karenina T, Irsan C, Pujiastuti Y. 2019. *Arthropods inhabiting flowering non-crop plants and adaptive vegetables planted around paddy fields of freshwater swamps of South Sumatra, Indonesia. Biodiversitas* 20: xxx. Local farmers in freshwater swamps of South Sumatra traditionally plant adaptive flowering vegetables surrounding paddy fields and let wild flowering plants or non-crop plants grow on the embankment. This research aimed to determine the species of non-crop plants and adaptive vegetables surrounding the freshwater swamp paddy fields as habitats and niches of arthropods. This study used four species of flowering non-crop plants (*Zinnia* sp., *Tagetes erecta*, *Cosmos caudatus*, *Sesamum indicum*) and four species of vegetables (*Vigna unguiculata*, *Momordica charantia*, *Cucumis sativus*, *Luffa acutangula*) planted around the paddy fields. While the arthropods were collected using sweep nets. There were 24 species of predatory arthropods, three species of parasitoids, 17 species of herbivores, and nine species of neutral insects found in the non-crop plants and vegetables. The non-crop plant and vegetable species that were the most chosen by the predatory arthropods were *Zinnia* sp. and *M. charantia*, respectively. Species of the non-crop plants and vegetables chosen by the parasitoids were *T. erecta* and *M. charantia*, respectively. Those non-crop plants and adaptive vegetables were also the most chosen plants by the predatory arthropods for their habitats and niches. Therefore, for the conservation of natural enemies, it is better to use *Zinnia* sp., *T. erecta*, and *M. charantia*.

**Keywords:** Herbivores, neutral insects, parasitoids, predatory arthropods, predatory insects



## INTRODUCTION

Freshwater swamps are wetlands saturated with water, either throughout the year or seasonally due to the influence of river water or rain. In Indonesia, freshwater swamps reach 9.2 Mha spreading across Sumatra, Kalimantan, and Papua (Mulyani and Sarwani, 2013). Freshwater swamps have three land typologies, namely shallow, middle, and deep, generally cultivated as adaptive plants (Siaga et al. 2019). All of the three land typologies are generally planted with paddy (Herlinda et al. 2018; Lakitan et al. 2018; Prabawati et al. 2019). On paddy fields planted in the shallow and middle swampy of lowlands, they are generally also planted with adaptive vegetables, such as chili (Johari et al. 2014, 2016), long beans, bitter melon, ridged gourd, eggplant, and cucumber (Siaga et al. 2019). On the embankments not planted with adaptive vegetables, they are generally not weeded, but wild plants (non-crop plants) can still grow there (Herlinda et al. 2019; Karenina et al. 2019). In addition, local farmers are not accustomed to applying synthetic pesticides (Herlinda et al. 2018).

Unnoticed by the farmers, the wild vegetables and plants can act as habitats and arthropod niches both as natural enemies and insect pests (Hassan et al. 2016; McCabe et al. 2017). Apart from being alternative habitats and niches for natural enemies, these wild vegetables and plants also act as niches due to providers of nectar and pollen (Karenina et al. 2019). The nectar and pollen can increase the longevity, fecundity, and fitness of adult natural enemies (Desai et al. 2017; Foti et al. 2017).

Some previous researches on the arthropods inhabiting plants have been done. According to Desai et al. (2017), in some species of flowering non-crop plants, for example, *Zinnia* sp., spiders (*Argiope aemula*, *Oxyopes* sp., and *Perenethis* sp.) are found settling. Furthermore, *Tagetes erecta* is inhabited by *Oxyopes javanus*, *Coccinella septempunctata*, *Syrphus* spp., *Geoceris* spp., *Apis dorsata*, *A. mellifera*, and *Vanessa cardui* (Ganai et al. 2017). The natural enemies of predatory arthropods, namely Pentatomidae and Mantidae and parasitoids from Eulophidae, Tachinidae, and Ichneumonidae are found in non-crop plants (*Antigonon leptopus*, *Turnera subulata*, and *Agreratum* sp.) (Saleh and Siregar 2017).

Paddy of freshwater swamps surrounded by vegetables, such as *V. sinensis*, *C. sativus*, *M. charantia*, and *L. acutangula* has an abundance and variety of arthropod predator species more than that not surrounded by the four vegetable species mentioned above (Karenina et al. 2019). Consequently, it is necessary to find out the species of non-crop plants and adaptive vegetables as habitats and niches of arthropods, especially predatory arthropods and parasitoids as natural enemies of paddy pest insects. The study aimed to determine the species of non-crop plants and adaptive vegetables surrounding the freshwater swamp paddy fields as habitats and niches of arthropods.

## MATERIALS AND METHODS

The study was carried out in the freshwater swamp paddy fields of Pelabuhan Dalam Village in Pemulutan Subdistrict of Ogan Ilir District of South Sumatra Province from May to November 2018. The identification of arthropod species was conducted from December to March 2019 by Dr. Chandra Irsan from Universitas Sriwijaya. The location of the study was carried out in a freshwater swamp paddy center surrounded by monoculture paddy on an area of  $\pm$  800 ha. In this study, four species of non-crop plants were planted in paddy fields surrounding 1 ha of freshwater swamp paddy and 1 ha of the other paddy plots was surrounded by four species of local vegetables planted in the embankment of paddy fields.

### Growing Non-crop plants and vegetables

The planting of non-crop plants and vegetables was carried out 30 days before planting paddy so that when it reached 14 days after transplanting (DAT), the non-crop plants and vegetables began to bloom. There were two paddy plots of 1 ha each. The first plot was surrounded by four species of non-crop plants: zinnia (*Zinnia* sp.), marigold (*Tagetes erecta*), kenikir (*Cosmos caudatus*), and sesame (*Sesamum indicum*) planted on four sides of the embankment. The second plot was surrounded by four species of vegetables: cowpea (*Vigna unguiculata*), bitter melon (*Momordica charantia*), cucumber (*Cucumis sativus*), and ridged gourd (*Luffa acutangula*). The spacing between planting holes was 30 cm for long beans, 60 cm for bitter melons, 40 cm for cucumbers, and 30 cm for ridged gourd. As for non-crop plants, the spacing between planting holes was 15 cm.

### Paddy planting

The stages of paddy planting started from tillage, seed treatment, nursery, transplanting, and fertilizing using manure and liquid compost extract. Land preparation and processing began with clearing weeds and then soil treatment while applying manure at a dose of 1 ton.ha<sup>-1</sup> and liquid compost extract at a dose of 2 L.ha<sup>-1</sup>. Liquid compost extract was made following the method of Suwandi et al. (2012) enriched with *Trichoderma virens*. The paddy seeds used *mekongga* variety, which was already treated using compost extract when ripening the seeds for 1 x 24 hours. After that, the seeds were sown and covered with a banana leaf on a plastic tray (size 36 cm x 27 cm x 4.5 cm) for 14 days. The 14-day-old paddy seedlings were transplanted into the fields with the 2:1 *legowo* row system with a planting space of 50 cm x 25 cm x 12.5 cm.

### Observation of arthropod inhabiting non-crop plants and vegetables

The observation of arthropod inhabiting non-crop plants and vegetables surrounding the paddy was conducted once a week, starting when the paddy reached 14 to 84 days after transplanting. This observation was a continuation of the

research of Karenina et al. (2019) who sampled by taking five flowers for each species of non-crop plants and vegetables, while in this study the sampling was carried out by observing directly and documenting arthropods that perched on non-crop plants flowers or leaves and vegetables at 07–08 a.m., 09–10 a.m., 12-01 p.m., and 04-05 p.m. Direct observations were conducted on five flowers for each species of non-crop plants and vegetables. The observations were made by recording and documenting the arthropods that perched. The inhabiting arthropods were identified based on their morphological characteristics. Identification of spiders referred to Barrion and Litsinger (1995) and identifying insects referred to Heinrichs (1994), Kalshoven (1981), and McAlpine et al. (1987).

### Data analysis

Arthropod composition and abundance data on non-crop plants and vegetables were analyzed descriptively and presented in tables and graphs. The arthropod abundance data were also further grouped by guild, namely predator (spiders and predatory insects), parasitoids, herbivores, and neutral insects to be displayed in graphical form. Data presented in Tabel 1–4 were counted from the mean of arthropod abundance from five flowers for each species of the plants during 11 observations (11 weeks). Data of Figure 2 were obtained from proportion of the total abundance of each guild and the total abundance of all guilds. The mean of arthropod family abundance from each plant was presented in Figure 3. Data of Figure 4 were obtained from the mean of abundance from each guild (predatory arthropod, parasitoids, herbivores, and neutral insects). Data presented in Figure 5 were counted from the mean of abundance from each guild sampled at 07-08 a.m., 09-10 a.m., 12-01 p.m., 04-05 p.m. Data for Figure 6 were obtained from the mean of arthropod abundance from each observation since 14 until 84 days.

## RESULTS AND DISCUSSION

### Arthropod abundance inhabiting non-crop plants and vegetables

Dominant arthropods inhabiting non-crop plants and vegetables were *Cosmophasis* sp., *Tetragnatha*

*mandibulata*, *Oxyopes javanus*, *Oxyopes* sp., *Odontoponera transversa*, *Menochilus sexmaculatus*, *Pantala* sp., and *Odontomantis planiceps* (Figure 1). The most dominant species of predatory arthropods at non-crop plants were *Odontomantis planiceps*, while at the vegetables, it was Coccinellidae (unknown species). During one paddy planting season, 24 species of predatory arthropods (spiders and predatory insects) were found inhabiting non-crop plants and vegetables. The species of non-crop plants most chosen by the predatory arthropods was zinnia (0.271 individuals/hill), while the adaptive vegetable chosen was bitter melon (0.039 individuals/hill) (Table 1). The number of species of predatory arthropods in zinnia and bitter melons was the largest, comprising 15 species and 6 species, respectively.

The parasitoid species found in non-crop plants were a large number of *Blondelia nigripes*, while those found in vegetables were *Sarcophagidae* (Table 2). During the paddy planting season, there were found 3 species of parasitoid families inhabiting the non-crop plants and vegetables. The highest parasitoid abundance in non-crop plants was found in zinnia and the highest parasitoid abundance in vegetables was found in bitter melons.

Species of herbivores or phytophagous species found in non-crop plants were *Pelopidas thrax*, while the species most commonly found in vegetables was *Aulacophora frontalis* (Table 3). During the paddy planting season, 17 species of herbivores were found inhabiting non-crop plants and vegetables. The highest abundance of herbivores in non-crop plants was found in zinnia and the highest abundance of herbivores in vegetables was found in the ridged gourd.

The species of neutral insects found in non-crop plants and vegetables was *Odontoponera transversa*. During the paddy planting season, nine species of neutral insects were found inhabiting non-crop plants and vegetables (Table 4). The highest abundance of neutral insects in non-crop plants was found in sesame, and the highest abundance of neutral insects in vegetables was found in cowpeas.

**Table 1.** Predatory arthropod abundance inhabiting non-crop plants and vegetables

| Species                        | Predatory arthropod abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|--------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                | Zinnia  | Marigold | Kenikir | Sesame | Cowpea | Bitter melon | Cucumber | Ridged gourd |
| <i>Pardosa</i> sp.             | 0.009   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Argiope</i> sp.             | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Tetragnatha virescens</i>   | 0   | 0        | 0       | 0      | 0.005  | 0            | 0        | 0            |
| <i>Tetragnatha mandibulata</i> | 0.023   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| Linyphiidae (unknown sp.)      | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| <i>Oxyopes matiensis</i>       | 0.032   | 0        | 0       | 0.005  | 0      | 0            | 0        | 0            |
| <i>Oxyopes javanus</i>         | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| Thomisidae (unknown )          | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Cosmophasis</i> sp.         | 0.045   | 0.018    | 0       | 0.014  | 0      | 0            | 0        | 0            |

|                                    |       |       |       |       |       |       |       |       |
|------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| <i>Salticidae</i> (unknown sp.)    | 0.005 | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| <i>Menochilus sexmaculatus</i>     | 0.014 | 0.005 | 0     | 0.005 | 0     | 0.014 | 0.009 | 0.009 |
| <i>Coccinellidae</i> (unknown sp.) | 0.005 | 0.009 | 0     | 0     | 0     | 0.005 | 0.018 | 0     |
| <i>Formicomus</i> sp.              | 0     | 0     | 0.005 | 0     | 0     | 0     | 0     | 0     |
| <i>Paederus fuscipes</i>           | 0.005 | 0     | 0     | 0     | 0     | 0.005 | 0     | 0     |
| <i>Chloropidae</i> (unknown sp.)   | 0     | 0.032 | 0.005 | 0     | 0     | 0     | 0     | 0     |
| <i>Chrysosoma leucopogon</i>       | 0.018 | 0.005 | 0     | 0     | 0     | 0.005 | 0     | 0     |
| <i>Eristalinus</i> sp.             | 0.005 | 0     | 0     | 0     | 0     | 0.005 | 0     | 0     |
| <i>Eristalis</i> sp.               | 0     | 0.009 | 0.018 | 0     | 0     | 0.005 | 0     | 0     |
| <i>Ropalidia marginata</i>         | 0     | 0     | 0.005 | 0     | 0     | 0     | 0     | 0.005 |
| <i>Odontomantis planiceps</i>      | 0.068 | 0     | 0     | 0.005 | 0     | 0     | 0     | 0     |
| <i>Archimantis</i> sp.             | 0     | 0     | 0.014 | 0     | 0     | 0     | 0     | 0     |
| <i>Mantidae</i> (unknown sp.)      | 0.014 | 0     | 0     | 0.005 | 0     | 0     | 0     | 0     |
| <i>Pantala flavescens</i>          | 0.018 | 0.027 | 0     | 0.005 | 0     | 0     | 0     | 0.005 |
| <i>Ictinogomphus</i> sp.           | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0.005 |
| Total of abundance                 | 0.271 | 0.11  | 0.057 | 0.039 | 0.005 | 0.039 | 0.027 | 0.024 |
| Total of species                   | 15    | 8     | 7     | 6     | 1     | 6     | 2     | 4     |

**Table 2.** Parasitoids abundance inhabiting non-crop plants and vegetables

| Species                            | Parasitoids abundance inhabiting non-crop plants dan vegetables (individual/hill) |          |         |        |        |              |          |              |
|------------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                                    | Zinnia  | Marigold | Kenikir | Sesame | Cowpea | Bitter melon | Cucumber | Ridged gourd |
| <i>Cryptochetum iceryae</i>        | 0.009   | 0.014    | 0.014   | 0.005  | 0.005  | 0            | 0        | 0            |
| <i>Sarcophagidae</i> (unknown sp.) | 0.009   | 0.018    | 0.009   | 0.005  | 0.005  | 0.014        | 0        | 0            |
| <i>Blondelia nigripes</i>          | 0.014   | 0.018    | 0.023   | 0      | 0      | 0.005        | 0        | 0.005        |
| Total of abundance                 | 0.032   | 0.05     | 0.046   | 0.01   | 0.01   | 0.019        | 0        | 0.005        |
| Total of species                   | 3   | 3        | 3       | 2      | 2      | 2            | 0        | 1            |

**Table 3.** Herbivore abundance inhabiting non-crop plants and vegetables

| Species                       | Herbivore abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|-------------------------------|---|----------|---------|--------|--------|--------------|----------|--------------|
|                               | Zinnia  | Marigold | Kenikir | Sesame | Cowpea | Bitter melon | Cucumber | Ridged gourd |
| <i>Chrysolina coeruleans</i>  | 0.018   | 0        | 0.005   | 0.005  | 0      | 0.014        | 0.009    | 0.009        |
| <i>Aulacophora frontalis</i>  | 0   | 0.005    | 0       | 0      | 0      | 0.073        | 0.014    | 0.482        |
| <i>Aulacophora indica</i>     | 0   | 0        | 0       | 0      | 0      | 0.005        | 0.151    | 0            |
| <i>Charidotella</i> sp.       | 0   | 0        | 0       | 0      | 0      | 0            | 0.005    | 0            |
| <i>Epilachna dodecastigma</i> | 0   | 0        | 0       | 0      | 0      | 0.059        | 0.005    | 0.023        |
| <i>Cletus trigonus</i>        | 0.036   | 0.009    | 0.005   | 0      | 0      | 0.032        | 0        | 0            |
| <i>Amata nigriceps</i>        | 0.018   | 0.045    | 0       | 0      | 0.018  | 0.050        | 0.009    | 0            |
| <i>Petrophora</i> sp.         | 0.005   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Perizoma</i> sp.           | 0   | 0.005    | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Pelopidas thrax</i>        | 0.291   | 0.041    | 0.036   | 0      | 0      | 0.077        | 0.005    | 0            |
| <i>Spodoptera</i> sp.         | 0.009   | 0        | 0       | 0      | 0      | 0.009        | 0        | 0            |
| <i>Eurema blanda</i>          | 0.009   | 0        | 0.023   | 0      | 0      | 0.014        | 0        | 0            |
| <i>Aporia</i> sp.             | 0.009   | 0.009    | 0.005   | 0      | 0      | 0            | 0        | 0            |
| <i>Valanga nigricornis</i>    | 0.123   | 0.041    | 0.032   | 0.045  | 0      | 0.050        | 0.100    | 0            |
| <i>Acrida turrita</i>         | 0.032   | 0.023    | 0.005   | 0.014  | 0      | 0            | 0        | 0.005        |
| <i>Oxya chinensis</i>         | 0.041   | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Tetrix subulata</i>        | 0   | 0        | 0.005   | 0      | 0      | 0            | 0        | 0            |
| Total of abundance            | 0.591   | 0.178    | 0.116   | 0.064  | 0.018  | 0.383        | 0.298    | 0.519        |
| Total of species              | 11  | 8        | 8       | 3      | 1      | 10           | 8        | 4            |

**Table 4.** Neutral insect abundance inhabiting non-crop plants and vegetables

| Species                           | Neutral insect abundance inhabiting non-crop plants and vegetables (individual/hill) |          |         |        |        |              |          |              |
|-----------------------------------|--|----------|---------|--------|--------|--------------|----------|--------------|
|                                   | Zinnia   | Marigold | Kenikir | Sesame | Cowpea | Bitter melon | Cucumber | Ridged gourd |
| <i>Chironomidae</i> (unknown sp.) | 0.005  | 0        | 0       | 0      | 0      | 0            | 0        | 0            |
| <i>Rainieria antennaepe</i> s     | 0.036  | 0.014    | 0.023   | 0.009  | 0.005  | 0            | 0.005    | 0.005        |
| <i>Neomyia cornicina</i>          | 0.009  | 0.005    | 0.018   | 0.027  | 0      | 0            | 0        | 0            |

|                                |       |       |       |       |       |       |       |       |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| <i>Chloromyia farmosa</i>      | 0.005 | 0     | 0.014 | 0     | 0     | 0     | 0     | 0.005 |
| <i>Hermetia</i> sp.            | 0.005 | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| <i>Tipula maxima</i>           | 0.045 | 0.009 | 0.014 | 0.005 | 0     | 0     | 0.005 | 0     |
| <i>Trigona</i> sp.             | 0.118 | 0.082 | 0.023 | 0     | 0     | 0.055 | 0     | 0.005 |
| <i>Apis cerana</i>             | 0     | 0.014 | 0     | 0     | 0     | 0     | 0     | 0     |
| <i>Odontoponera transversa</i> | 0     | 0.009 | 0     | 0.273 | 0.815 | 0     | 0     | 0.345 |
| Total of abundance             | 0.223 | 0.133 | 0.092 | 0.314 | 0.82  | 0.055 | 0.01  | 0.36  |
| Total of species               | 7     | 6     | 5     | 4     | 2     | 1     | 2     | 4     |

### Arthropod community and guilds inhabiting non-crop plants and vegetables

The arthropod community inhabiting non-crop plants and vegetables varied between plant species. Guild of herbivores was predominantly found in all of the non-crop plants and vegetable species, except sesame and cowpea (Figure 2). The sesame and cowpea were dominated by a neutral insect community, primarily *Odontoponera transversa*.

The arthropod community inhabiting non-crop plants and vegetables varied between plant species (Figure 3). They were dominated by four families, namely Hesperidae, Apidae, Formicidae, and Chrysomelidae. Arthropods inhabiting *Zinnia* sp. and *C. caudatus* were dominated by the Hesperidae; the marigolds were dominated by the

Apidae; the sesame and cowpea were dominated by Formicidae; and the bitter melon, cucumber, and ridged gourd were dominated by Chrysomelidae.

The highest abundance predators inhabiting non-crop plants was found in zinnia. The highest abundance of predators inhabiting zinnia was followed by that of herbivores and neutral insects (Figure 4). There was a link among the abundance of predators, herbivores, and neutral insects inhabiting the plants. The highest abundance of predators inhabiting vegetables was found in bitter melons, followed by parasitoids and herbivores. The high abundance of predators in bitter melons was not followed by that of neutral insects. The highest abundance of neutral insects in vegetables was found in cowpeas.



**Figure 1.** Dominant arthropod species inhabiting non-crop plants and vegetables: *Cosmophasis* sp. (A), *Tetragnatha mandibulata* (B), *Oxyopes javanus* (C), *Oxyopes* sp. (D), *Odontoponera transversa* (E), *Menochilus sexmaculatus* (F), *Pantala* sp. (G), *Odontomantis planiceps* (H), *Pelopidas* sp. (I), *Amata nigripes* (J), *Aulacophora indica* (K), *Valanga nigricornis* (L), *A. frontalis* (M), *Tipula* sp. (N), *Trigona* sp. (O), and *Rainieria antennaepe* (P)

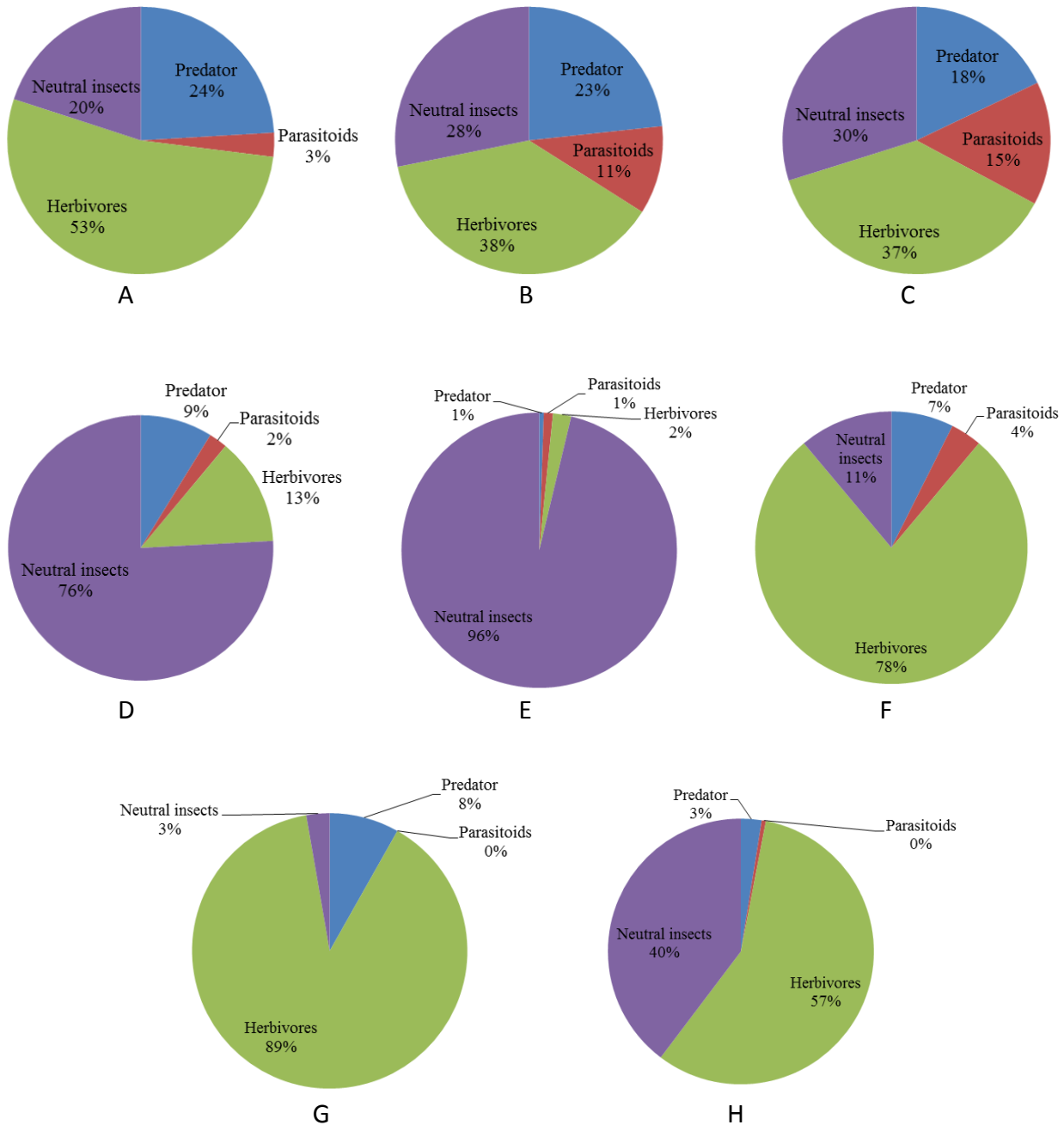
The abundance of four community guilds of arthropods inhabiting non-crop plants and vegetables had a different tendency (Figure 5). Predators visited non-crop plants and vegetables all day from morning to evening. Predators tended visit Zinnia in the afternoon and evening, *C. caudatus* in the morning and evening, cowpea and bitter melon in the morning, and ridged gourd in the afternoon and evening. Parasitoids generally visited non-crop plants and vegetables in the morning, for example zinnia, marigolds, sesame, and bitter melons were visited at 07–08 a.m., while *C. caudatus* and cowpea were mostly visited at

09–10 a.m. However, ridged gourd was visited by parasitoids in the afternoon at 04–05 p.m. Among those flowers, the marigolds were the most chosen by the parasitoids. Herbivores visited non-crop plants and vegetables throughout the day, while many neutral insects visited non-crop plants and vegetables in the morning.

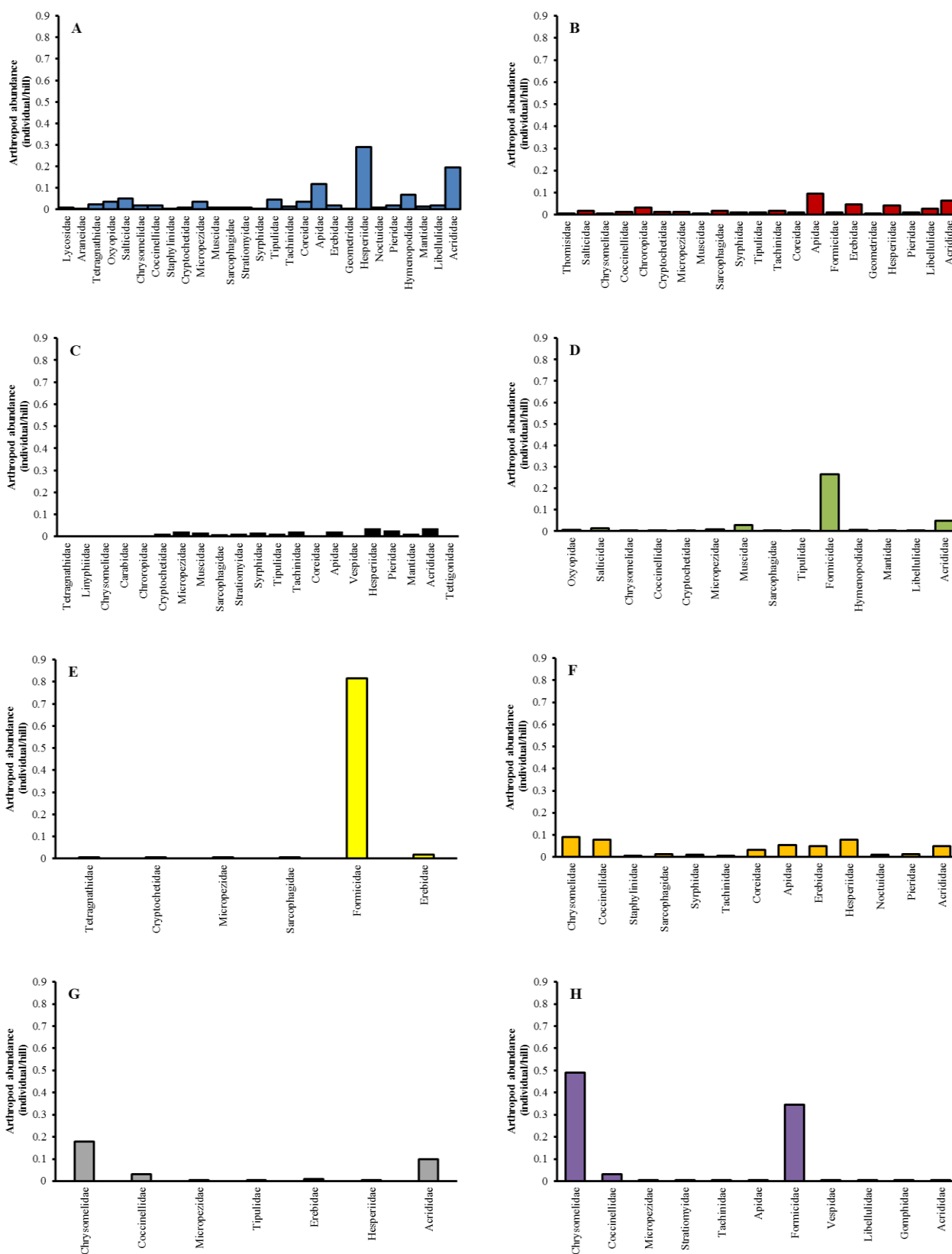
The abundance of guild arthropods found in non-crop plants and vegetables fluctuated during one paddy planting season. When paddy was initially planted, the abundance of arthropods found in non-crop plants and vegetables tended to be lower and continued to increase and reached a peak in

the ripe phase of milk (56-70 DAT), nearing the harvest it tended to decline. During one planting season, the abundance of herbivores in zinnia, bitter melons, cucumber, and ridged gourd was always higher compared to other guilds, whereas in sesame and cowpeas, the

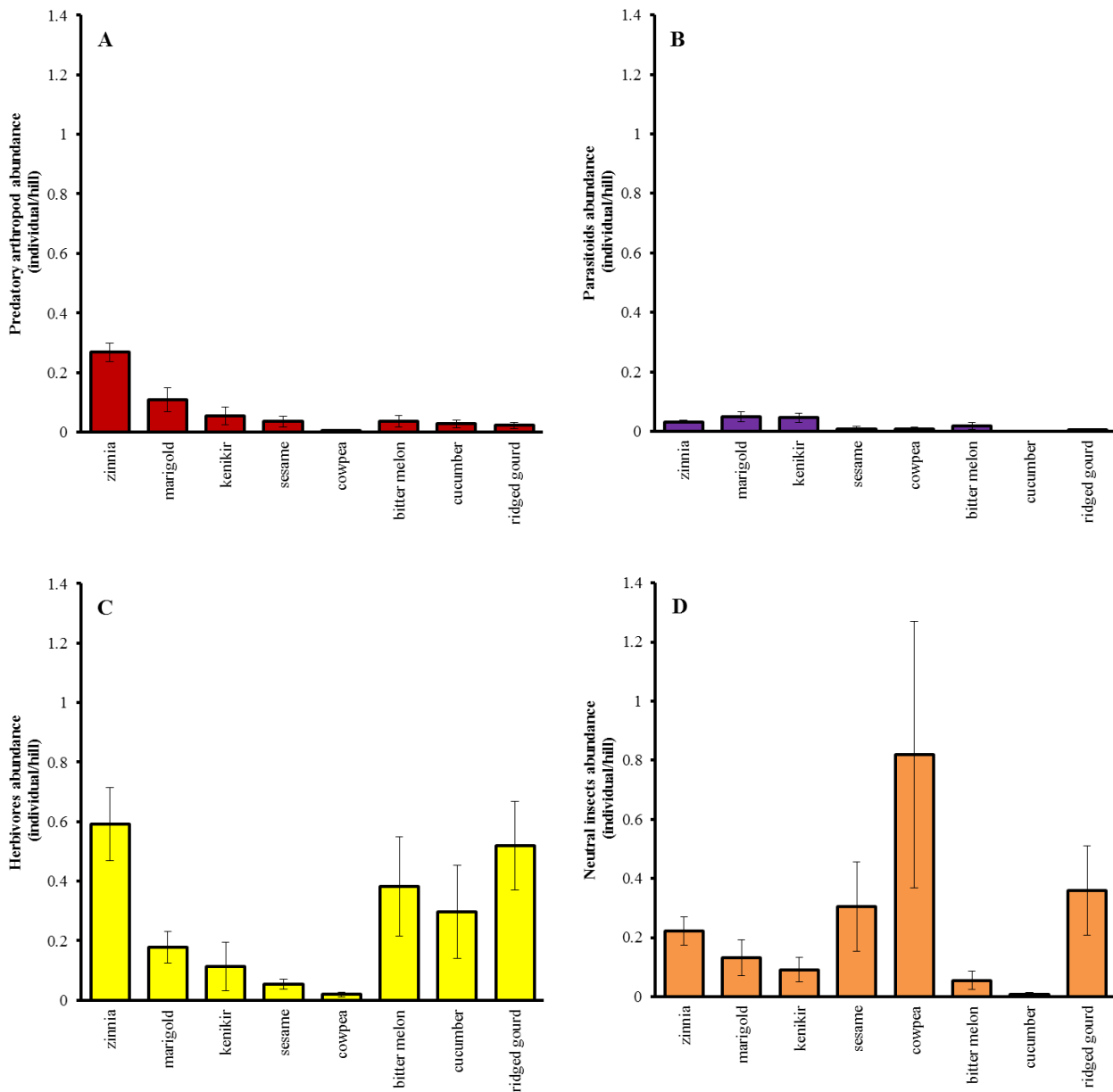
abundance of neutral insects was always high (Figure 6). The abundance of predators and herbivores was highest in zinnia., The abundance of predators tended to be affected by the fluctuations of herbivores' abundance.



**Figure 2.** Proportion of arthropod guilds inhabiting non-crop plants dan vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)



**Figure 3.** The mean abundance of arthropod family inhabiting non-crop plants and vegetables: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)



**Figure 4.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables

## Discussion

*Cosmophasis* sp., *T. mandibulata*, *O. javanus*, *Oxyopes* sp., *O. transversa*, *M. sexmaculatus*, *Pantala* sp., and *O. planiceps* were paddy pest insect predators in this study. In line with Tahir et al. (2009), *T. mandibulata* are predators of Homoptera and Lepidoptera on paddy. *O. javanus* and *Oxyopes* spp. can attack, among others, *Sogetella furcilera*, and *Scripophaga innotata* on paddy in Pakistan (Tahir et al. 2009). *M. sexmaculatus* and Coccinellidae are generalist predators (Karindah, 2011) able to prey on *N. virescens* and *N. lugens* on paddy in India (Shanker et al. 2018).

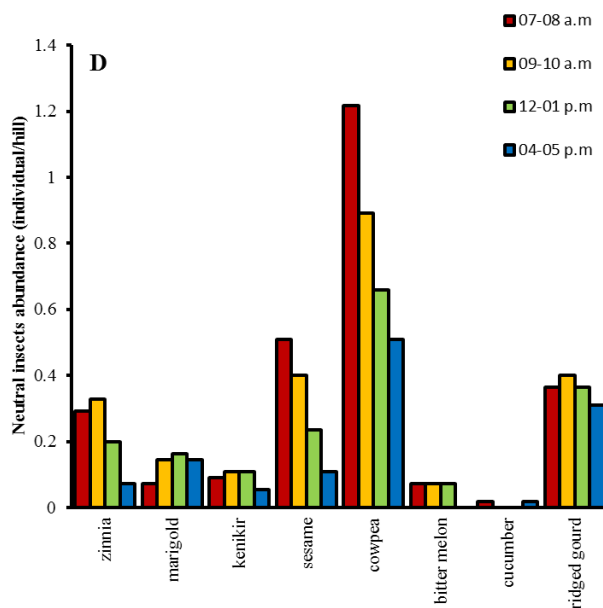
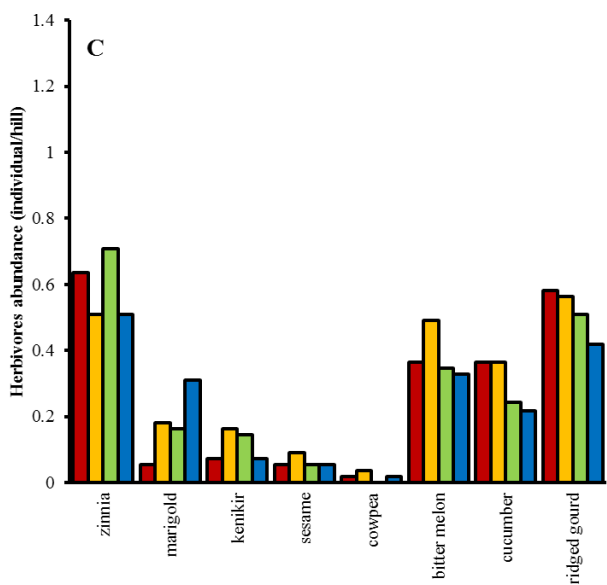
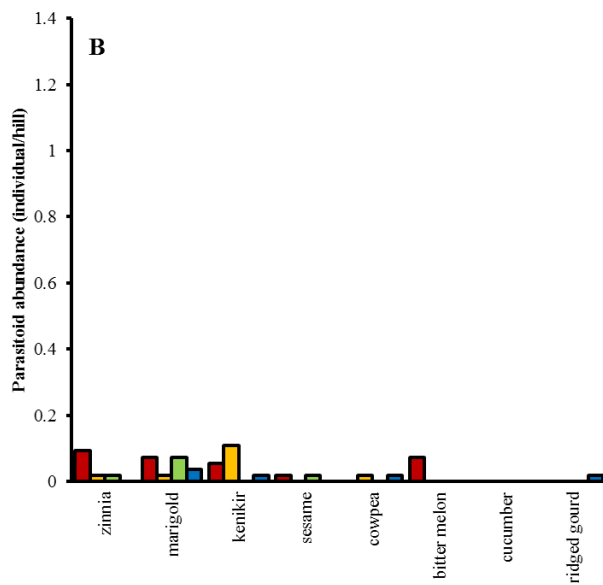
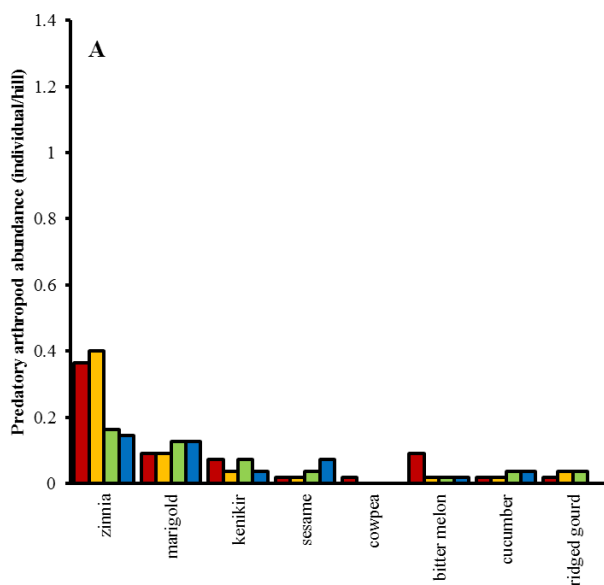
At zinnia and bitter melon, the abundance of predators is higher than the abundance in six other plant species. Zinnia is preferred because of its longer blossoming period, and Wahocho et al. (2016) stated that *Zinnia* sp. can bloom for 23,67 days (Wahocho et al. 2016). Bitter melon has a yellow color preferred by the predatory arthropods compared to other colors. In line with the study of Rocha-Filho and Rinaldi (2011), arthropods prefer yellow flowers rather than white and pink flowers. In this study, the abundance of herbivores in zinnia and bitter melons can affect the abundance of these generalist predators. This phenomenon is common because generalist predators look for prey (Karenina et al. 2019). Zinnia and bitter melon are



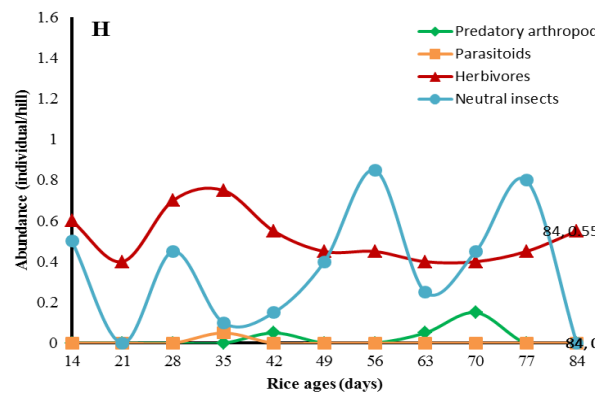
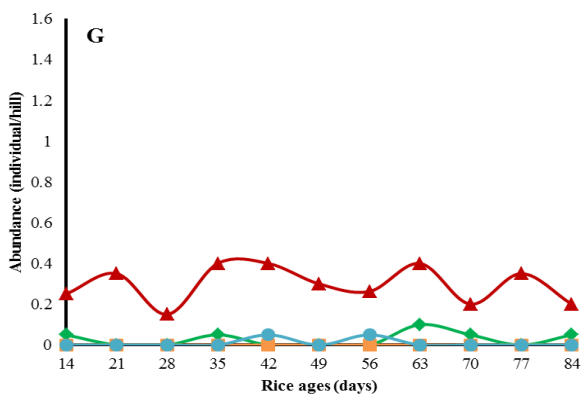
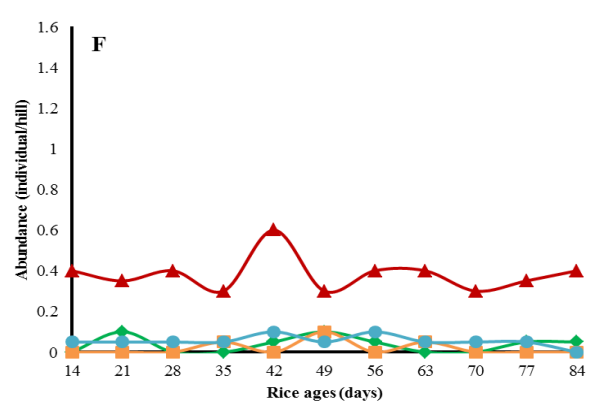
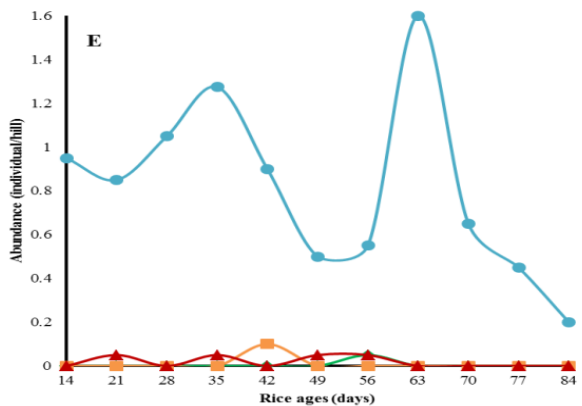
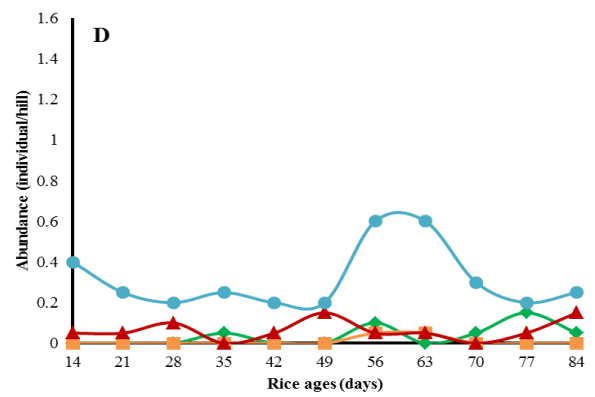
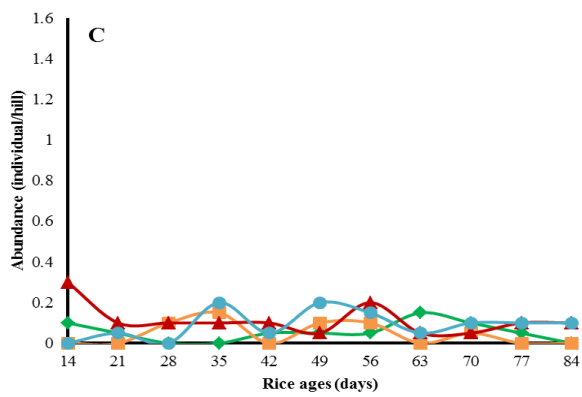
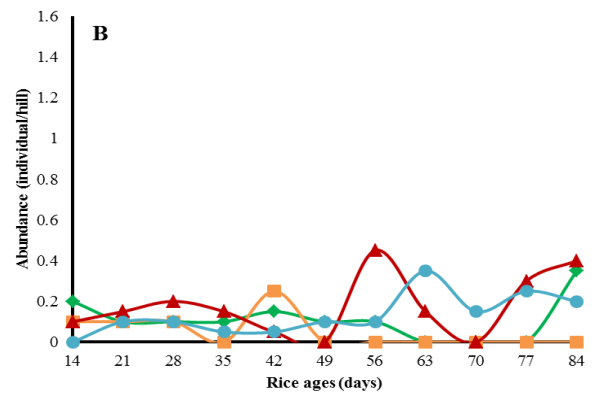
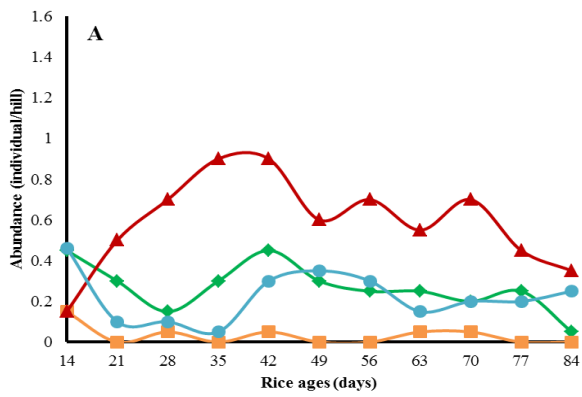
also the most chosen parasitoids for their habitat. The shape of the rosette flower of *Zinnia* sp. and bitter melon is highly attracted to predators and parasitoids. In line with the opinion of Jennings et al. (2017), the rosette-shaped flowers are visited by arthropods longer. Pollen and nectar existing in non-crop plants flowers and vegetables can also increase the attractiveness of flowers for niche arthropods, such as spiders (Eggs and Sanders 2013) and parasitoids (Foti et al. 2017).

The guild of herbivores dominated in all of plant species except sesame and cowpea. The species are *Valanga nigricornis*, *Acrida turrita*, and *Oxya chinensis*, which are grasshoppers and not key pests. However, the presence of herbivores in these plants is useful for prey generalist predators which are natural enemies of key pests

in paddy. In herbivores of non-crop plants and vegetables, there are no key pests such as *Nilaparvata lugens*, *Nephotettix virescens*, *Sogatella furcifera*, and *Leptocorisa acuta* that attack paddy. Therefore, the presence of non-crop plants and vegetables does not function as an alternative habitat for key pests but acts as a habitat and niche for natural enemies and herbivores, which are not key pests. Still, the herbivores have an important role as alternative prey for predatory arthropods. Settle et al. (1996) pointed out that herbivores, which are not key pests, are also important in the presence of agroecosystems for prey generalist predators, and so are neutral insects that are important as stocks of predator-prey if the key pests are not found in paddy.



**Figure 5.** Guild abundance of predatory arthropod (A), parasitoids (B), herbivores (C), and neutral insects (D) inhabiting non-crop plants and vegetables at 07-08 a.m, 09-10 a.m, 12-01 p.m, 04-05 p.m



**Figure 6.** Abundance arthropod inhabiting non-crop plants and vegetables in the period 14-84 days after transplanting: zinnia (A), marigold (B), *kenikir* (C), sesame (D), cowpea (E), bitter melon (F), cucumber (G), and ridged gourd (H)

In this study, *O. transversa* is an ant classified as a neutral insect commonly found in sesame and cowpea because this group of ants is associated with the cucumber, which attacks both plants. The presence of ants (Formicidae) in sesame and cowpea can reduce the arrival of parasitoids and predators in these plants. The presence of the ants reduces the comfort of parasitoids and predatory arthropods to settle and look for a host or prey. In line with the results of the research conducted by Sanders et al. (2011), ants can reduce spider activity in suppressing and reducing herbivores populations. Species diversity and spider abundance decrease significantly when the habitat is inhabited by ants (Stefani et al. 2015). Consequently, sesame and cowpea are less suitable to be used as refugia functioning to conserve parasitoids and predatory arthropods, which are natural enemies of paddy pests.

The highest parasitoid abundance is found in marigolds which are commonly found in the morning. The marigold is preferred because it has a longer availability of pollen and nectar. This is because it is able to bloom for 48.47 days (Gobade et al. 2017). The marigold yellow color is an attraction for parasitoid to perch and suck the nectar. The shape and color of marigolds are the most ideal for parasitoids looking for food (Souza et al. 2019). Several types of parasitoid Brassicaceae pests found inhabiting marigolds, for example, the Family Braconidae, Ichneumonidae, Eulophidae, and Pteromalidae (Velcheva et al. 2017) and Tachinidae (Razmi et al. 201).

To sum up, the non-crop plants to be recommended for the conservation of parasitoids and predators of paddy pests are zinnia and marigolds, while the recommended crop is bitter melon. However, for increasing land productivity while at the same time preserving predators and parasitoids, planting bitter melon in paddy fields is more profitable than planting zinnia and marigolds.

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