

DIVERSITY OF INSECT PESTS AND THEIR NATURAL ENEMIES IN HOT PEPPER (*CAPSICUM ANNUM* L.) ECOSYSTEM OF INDONESIA

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(Received 3rd Feb 2022; accepted 20th May 2022)

Abstract. The objective of this study was to determine the diversity and structure of insect communities in hot pepper ecosystem of Indonesia. The study was carried out in Lembang, in 2020 using yellow sticky and fruit fly traps. The study showed 18 insect families belonging to the following orders: Coleoptera, Diptera, Hemiptera, Hymenoptera, Thysanoptera and Lepidoptera. These families consisted of 23 species and 45,489 individuals. The Shannon-Wiener (H') diversity index showed that the ecosystem had low to moderate diversity, which increased from planting to harvesting stages. The species evenness index (E) was low during the vegetative growth and increased during reproductive and harvesting stages. Simpson's dominance index (D) decreased with increasing diversity, from medium to low dominance category.

Keywords: abundance, beneficial insect, dominance, hot pepper, phytophagous

Introduction

Hot pepper (*Capsicum annum* L.) is an important vegetable crop with high economic value grown in tropical and subtropical regions throughout the world (Hundall and Dhall, 2004; Cakrabarty et al., 2019). Hot pepper is used as a source of nutrients that are beneficial for health (Shetty et al., 2013; Padilha and Barbieri, 2016; Saleh et al., 2018), as a source of vitamins and minerals (Kerketta et al., 2018), and as a cooking spice and coloring (Pugliese et al., 2013; Materska, 2014; Loizzo et al., 2015). Hot pepper is widely cultivated in developing countries, including Indonesia (Lin et al., 2015; Ganefianti et al., 2017) and it is a special commodity because it can cause inflation (Mariyono, 2016).

Hot pepper consumption per capita in Indonesia was 2.9 kg per year (Farid and Subekti, 2012). However, national hot pepper production is still relatively low, at around 8.82 tons/ha (Ministry of Agriculture, Republic of Indonesia, 2019), even though the potential yield can reach 20 tons/ha (Soetiarso and Setiawati, 2010). One of the causes of low hot pepper productivity is pests that could result in yield losses

between 50% and 90%, so farmers rely heavily on pesticides to control them (Setiawati et al., 2011).

In Indonesia, vegetative stages of hot pepper were injured by several insect pest such as cotton jassid (*Empoasca lybica* [*Jacobiasca lybica*]), thrips (*Thrips parvispinus*), oriental fruit fly (*Bactrocera dorsalis*), tropical armyworm (*Spodoptera litura* [*S. littoralis*]), and yellow tea mite (*Polyphagotarsonemus latus*). During fruiting and harvesting stages, the hot pepper were injured by cotton boll worm (*Helicoverpa armigera*) and oriental fruit fly (*Bactrocera dorsalis*) (Vos and Frinking, 1998). About 80% of farmers in Bangladesh use pesticides (Alam et al., 2016). However, the yield losses were still quite high, around 26% to 40% (Islam et al., 2020). Therefore, the chemical control methods need are evaluated.

Initial steps are necessary to develop appropriate control strategies is an information about the diversity of insect pests and their natural enemies in the hot pepper ecosystem. Such information can be used as a baseline to determine the next steps of sustainable pest control. Moekasan et al. (2004) reported that insecticide residue in hot pepper fruits in routinely sprayed conventional system have surpassed the maximum residue level.

The objective of this study was to determine the diversity and structure of insect communities in hot pepper ecosystem of Indonesia.

Methodology

Place and time of study

The study was conducted at the Margahayu Research Field Station, Lembang, West Java, Indonesia from March to October 2020.

Research design

The experiment was carried out on an unsprayed hot pepper crop sizing of size of 900 m² (30 m x 30 m). The 9 light traps (set at an interval of 15 m) and 5 yellow sticky traps (set at an interval of 15 m) were installed inside planting area and 4 fruit fly traps (set at an interval of 30 m) were installed outside planting area. All traps were installed on the planting day to trap the insect pests and natural enemies.

Pancanaka Agrihorti variety of hot pepper was grown using basic fertilizers that were applied at seven days before planting: chicken manure 20 t ha⁻¹, N 220 kg ha⁻¹, P₂O₅ 110 kg ha⁻¹ and K₂O 180 kg ha⁻¹ (Moekasan et al., 2014).

Weekly observations were made on 50 randomly selected sample plants and tagged, starting at 14 days after planting. On each sample plant, sucking insects such as aphids, thrips, whiteflies and leafhoppers found on the two shoots were recorded. While numbers of caterpillars or Lepidopteran larvae found on entire sample plant were counted. Numbers of insects caught in light traps was recorded twice a week, started from seven days after planting. The number and type of insects trapped on the yellow sticky traps and fruit fly traps were determined every week.

Insects identification

Insects sampled by each method were counted and separated according to species. Identification was carried out using insect identification keys by Borror et al. (1976) and Kashoven (1981).

Data analysis

The pest population recorded during the observation then subjected into the following formulas to obtain the value of insect abundance, diversity, evenness and dominance. There was no statistical analysis conducted following the calculation.

1. Relative abundance was calculated using the following formula (Krebs, 1978):

$$RA = \frac{n}{N} \times 100\% \quad (\text{Eq.1})$$

where RA = relative abundance; n = number of individuals of the focal insect species; N = total number of individual insect.

2. The Shannon-Wiener diversity index was calculated using the formula (Krebs, 1978):

$$H' = \sum_{i=1}^S P_i \ln P_i \quad (\text{Eq.2})$$

where H' = Shannon-Wiener diversity index; P_i = relative abundance of species i ; S = number of species found.

Classification of Shannon-Wiener diversity index values:

- < 1 = low species diversity, low distribution of individuals per species and usually interpreted as low community stability
- 1–3 = medium species diversity, distribution of the number of individuals of each species is moderate and interpreted as the stability of the community is moderate
- > 3 = high species diversity, distribution of the number of individuals of each species is high and community stability is interpreted as high

3. The evenness index or E was calculated using the following formula (Odum, 1971):

$$E = \frac{H'}{H_{\max}} \quad (\text{Eq.3})$$

where E = evenness index; H' = Shannon-Wiener diversity index; $H_{\max} = \ln S$ (S = number of species found).

Classification of evenness index values (Odum, 1971):

- $0 < E \leq 0.5$ = depressed community
- $0.5 < E \leq 0.75$ = unstable community
- $0.75 < E \leq 1$ = stable community

4. Simpson's dominance index was calculated using the following formula (Odum, 1971):

$$C = \sum_{i=1}^S (P_i)^2 \quad (\text{Eq.4})$$

where C = dominance index; P_i = relative abundance of species i ; S = number of insect species found.

Classification of dominance index values (Simpson, 1946 cited in Odum (1971):

$0 < C \leq 0.5$ = low dominance

$0.5 < C \leq 0.75$ = medium dominance

$0.75 < C \leq 1$ = high dominance

Results and discussion

Insects abundance

Insects found during planting period of hot pepper belong to the order Coleoptera, Diptera, Hemiptera, Hymenoptera, Thysanoptera and Lepidoptera. Insects of the orders as a whole consisting of 18 families. All orders were found in vegetative, reproductive and harvest (Fig. 1).

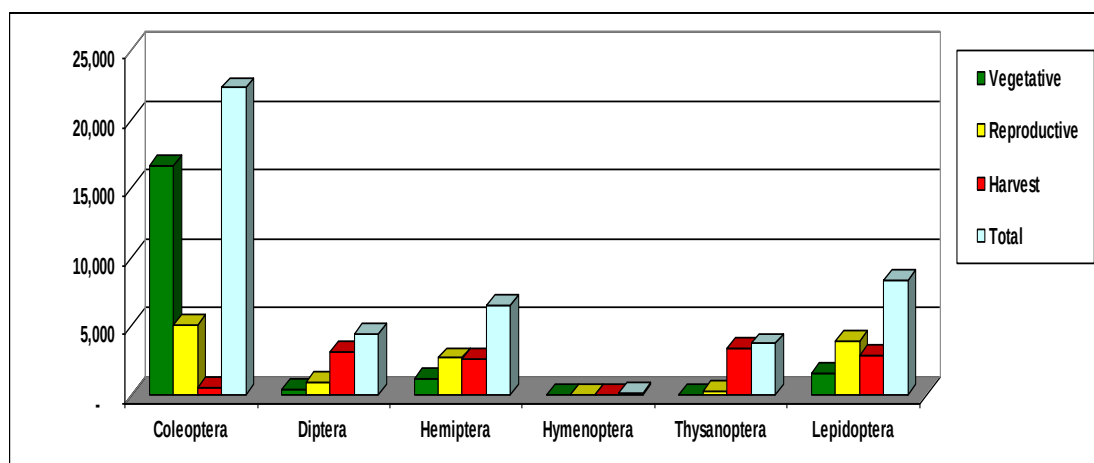


Figure 1. Population density within insect orders found in hot pepper ecosystem

The relative abundance of insects associated with hot pepper plants is shown in Table 1. The highest populations of insects were from the order Coleoptera during the vegetative and reproductive growth stages. For the order Diptera (fruit fly, the highest populations occurred during the harvesting phase when the hot pepper fruits as its' target were abundance. The populations of insects from the order Hemiptera which consists of leafhoppers, whiteflies and aphids increased in the reproductive and harvest growth stages, when the hot pepper leaves, which were their target, were dense. Compared to other orders, Hymenoptera populations was the lowest. Population densities of parasitoids was very low, even though the hot pepper field was not sprayed with insecticides. The intensively insecticides sprayed vegetable crops surrounding the hot pepper experiment field could be the cause of the low density of parasitoids in that area.

The populations of Thysanoptera which is the main pest of hot pepper in the vegetative and reproductive growth stages was low but increased when crop reached harvesting time. This might be because Thysanoptera competed with Hemiptera, which both have a same niche i.e. the shoots of hot pepper plants. The highest Lepidoptera populations occurred during the plants' reproductive growth stage, followed by harvest stage, that could be due to the abundance leaves and fruits in these stages.

Table 1. Relative abundance of insects in hot pepper ecosystem

Plant growth stages (weeks after transplanting [WAT])	Orders	Relative abundance (%)
Vegetative (0 – 8 WAT)	Coleoptera	83.5
	Diptera	2.0
	Hemiptera	6.2
	Hymenoptera	0.1
	Thysanoptera	0.4
	Lepidoptera	7.7
Reproductive (9 – 16 WAT)	Coleoptera	39.4
	Diptera	7.0
	Hemiptera	21.0
	Hymenoptera	0.4
	Thysanoptera	1.9
	Lepidoptera	30.4
Harvest (17 – 22 WAT)	Coleoptera	4.2
	Diptera	24.7
	Hemiptera	20.8
	Hymenoptera	0.5
	Thysanoptera	27.0
	Lepidoptera	22.9

During the vegetative stage, the insect population of the order Coleoptera which consisted of predatory and pest beetles was the largest with an abundance value of 83.5%. However, during this time, the populations of insect pests that feed on leaves were still low because the plants were still small. During the reproductive stage, insect populations within the order Coleoptera were the largest (39.4%) followed by Lepidoptera (30.4%) and Hemiptera (21%). Species of pests such as *Spodoptera litura* and *Aphis gossypii* increased as the plants grew. In addition, during the harvest stage, Thysanoptera had the highest populations (27.0%), followed by Diptera (24.7%), Lepidoptera (22.9%) and Hemiptera (20.8%). Populations of Hymenopteran parasitoids were the lowest, throughout the growing season.

Insects associated with hot pepper plants are shown in Table 2. The Coccinellidae family caught in sticky traps only contained one species i.e. *Menochilus sexmaculatus*, which is a predator of thrips, aphids and whiteflies. Nelly et al. (2012) and Efendi et al. (2016) stated *M. sexmaculatus* as a biological agent because its predatory activity increased with the increasing prey density.

The families Staphylinidae (*P. fuscipes*) and Cicindellidae (*Cicindella* sp.) caught by light traps, are important ground-dwelling predators with a wide host range, including eggs and larvae of Lepidoptera (Vijayaravendra et al., 2019; Zuharah and Maryam, 2020; Rewics and Jaskula, 2018). There were Scarabaeidae imago caught in the light traps, while its larvae commonly attacking crops root (Alfatah et al., 2020).

There were four families of Diptera caught in sticky traps, included (1) Tachinidae, the parasitoids of Lepidopteran larvae, (2) Cecidomyiidae species that known as rice plants pest, (3) Tephritidae (*Bactrocera* spp.), the hot pepper fruits pest, and (4)

Ceratopogonidae which were predators of small insects larvae of (Kalshoven, 1981; Kurniawati, 2015).

Table 2. Insects encountered in hot pepper ecosystem

No.	Family	Species	Number of individual insect	Nature of insect	Plant part harboured/prey
I. Coleoptera					
1.	Coccinellidae	<i>Menochilus sexmaculatus</i>	56	Predator	Thrips, aphids, whiteflies
2.	Staphylinidae	<i>Paederus fuscipes</i>	21,815	Predator	Eggs and larvae of Lepidoptera
3.	Cicindellidae	<i>Cicindella</i> sp.	17	Predator	Larvae of Lepidoptera
4.	Scarabaeidae	<i>Aphodius</i> sp.	408	Pest	Roots
II. Diptera					
5.	Tachinidae	<i>Tritaxis braueri</i>	2,533	Parasitoid	Larvae of Lepidoptera
6.	Cecidomyiidae	<i>Orseolia</i> sp.	93	Pest, visitor	Leaves
7.	Tephritidae	<i>Bactrocera</i> spp.	127	Pest	Fruits
8.	Ceratopogonidae	<i>Forcipomyia</i> spp.	1,667	Predator	Small larvae of insects
III. Hemiptera					
9.	Cicadellidae	<i>Empoasca</i> sp.	2,603	Pest	Leaves
10.	Aleyrodidae	<i>Bemisia tabaci</i>	873	Pest	Leaves
11.	Aphididae	<i>Aphis gossypii</i>	3,095	Pest	Leaves
IV. Hymenoptera					
12.	Ichneumonidae	<i>Diadegma semiclausum</i>	111	Parasitoid	Larvae of <i>P. xylostella</i>
13.	Braconidae	<i>Cotesia</i> sp.	27	Parasitoid	Larvae of <i>P. xylostella</i>
V. Thysanoptera					
14.	Thripidae	<i>Thrips parvispinus</i>	3,721	Pest	Leaves
VI. Lepidoptera					
15.	Noctuidae	<i>Spodoptera litura</i>	508	Pest	Leaves, fruits
		<i>Spodoptera exigua</i>	482	Pest	Leaves
		<i>Spodoptera frugiperda</i>	255	Pest, visitor	Corn
		<i>Plusia chalcites</i>	62	Pest	Leaves
		<i>Helicoverpa armigera</i>	384	Pest	Fruits
		<i>Agrotis ipsilon</i>	258	Pest	Young plants
16.	Gelechiidae	<i>Phthorimaea operculella</i>	612	Pest, visitor	Potato
17.	Plutellidae	<i>Plutella xylostella</i>	5,096	Pest, visitor	Cabbage
18.	Crambidae	<i>Crociodolomia binotalis</i>	688	Pest	Cabbage
Total			45,489		

The order Hemiptera was represented by three families, i.e.: Cicadellidae (*Empoasca* sp.), Aleyrodidae (*Bemisia tabaci*) and Aphididae (*Aphis gossypii*). *Empoasca* sp., the secondary pest of hot pepper plants, that could become a major pest if the population of the competitors are low and the temperature is extremely high (Vos and Frinking, 1998). *Bemisia tabaci* (Aleyrodidae), which known as the Gemini Yellow Virus vector, commonly found in low population as temporary visitor in hot pepper crops (Sudiono and Yasin, 2006). *Aphis gossypii* (Aphididae) is a pest of hot pepper plants as well as a vector for several types of viruses, including the mosaic virus in hot pepper (Suwandi, 2020).

The Hymenopteran found consisted of two families, namely Ichneumonidae (*Diadegma semiclausum*) and Braconidae (*Cotesia* sp.) which are larvae parasitoids of the cabbage pest, *Plutella xylostella* (Kahuthia-Gathu and Othim, 2019). The hot pepper fields were surrounded by brassica crops which explains why cabbage pest parasitoids were caught by the yellow sticky traps.

The Thysanopteran caught in yellow sticky traps consisted of one species, namely *Thrips. parvispinus*, which is the main pest of hot pepper plants (Murtiningsih et al., 2021).

The captured Lepidopteran insects consisted of four families i.e.: (1) Noctuidae family which included *Spodoptera litura*, *Spodoptera exigua*, *Plusia chalcites*, *Helicoverpa armigera*, and *Agrotis ipsilon* were hot pepper pests (Murtiningsih et al., 2021), but *Spodoptera frugiperda* is a pest of corn planted around hot pepper fields. Gelechiidae (*Phthorimaea operculella*) is a potato pest, while Plutellidae (*P. xylostella*) and Crambidae (*Crociodolomia binotalis*) are cabbage pests. Potatoes and cabbage were planted around the hot pepper fields. All Lepidopteran insects were found in light traps.

Species diversity

The species diversity index states the stability of an ecosystem. The higher the value of the species diversity index, the more stable the ecosystem. The diversity of species in the hot pepper ecosystem from the vegetative growth stage to harvest has increased, from low to medium diversity ($H' = 0.87$ to 2.32). The uniformity index in the vegetative growth stage showed that the number of species was low, then became unstable during the reproductive and harvest stages ($E = 0.28$ to 0.75). Meanwhile, the dominance index (C) decreased from 0.68 to 0.14 (Table 3).

Table 3. Diversity index, evenness index, and dominance index of insect species in hot pepper ecosystem

Plant growth stages	Diversity index	Evenness index	Dominance index
Vegetative (0 – 8 WAT)	0.87	0.28	0.68
Reproductive (9 – 16 WAT)	1.98	0.64	0.21
Harvest (17 – 22 WAT)	2.32	0.75	0.14

The three parameters of diversity indicated that at first the hot pepper ecosystem was unstable, depressed and medium dominated, because it was dominated by only one species from order Coleoptera. Furthermore, along with the growth of hot pepper plants, the number of leaves increased so that colonization of insect species increased. This condition caused the dominance of the species decreasing. Thus, the ecosystem stability increased, it was still moderately unstable. In the harvest stage, the fruit pest populations increased, which made the dominance of the species decreased. Although the stability of the hot pepper ecosystem slightly increased it was still at a moderate level.

Without insecticide applications, the high stability yield of the hot pepper ecosystem could not be maintained. That could be caused by the high correlation of pest population and yield reduction. Based on 17 years' observation, Furlan et al. 2020 found the significant correlation between seasonal *Agriotes* spp. (maize pest) adult catches in-field, subsequent wireworm populations, and plant damage/yield reduction in which plant damage increase with the increase of pest population. Paudel et al. 2021 additionally mentioned that in the context of climate change, the increasing temperatures at higher latitudes or temperate regions could resulting the higher insect abundance and consequently increasing the crop losses.

There was limited natural enemies species of chili pepper pest found in the field, and only a low number of *M. sexmaculatus* was found in the field. Therefore, the population of natural enemies should be increased to be able to suppress pest population, reduce the dominance of pest species and increase the ecosystem stability. Habitat manipulation, for instance the implementation of intercropping of hot pepper and refugee flowering plants such as maize, basil and marigold, could conserve the natural enemies since this system provide nectar, pollen and shelter (Kumar et al., 2013; Aldini et al., 2019; Anggraini et al., 2020; Habibi and Fuadah, 2021). Intercropping planting system could also reduce pests populations and crop damage (Ellahi et al., 2017). Letourneau et al. (2011) reported that presence of refugee plants could increase the number of natural enemies by 72% and reduce the number of pest population by 74%.

Implementation of control threshold is the other tactic for reducing insecticide application. Setiawati et al. (2013) reported that it could reduce insecticide application up to 73.33%. Moekasan et al. (2004) mentioned that it could reduce the pesticide residue in fruits under the maximum residue level. Additionally, it is important to develop genetically resistance hot pepper varieties against various detected pests. Until recently, the work on developing chili pepper resistance against pests that have been done included against *T. parvispinus* and *T. occidentalis* (Maharijaya et al., 2011) and against fruit fly (Kirana et al., 2021).

Conclusions

The insects found in the hot pepper ecosystem belong to the Order of Coleoptera (four families), Diptera (four families), Hemiptera (three families), Hymenoptera (two families), Thysanoptera (one family) and Lepidoptera (four families). Altogether there were 23 species and 45,489 individuals. The Shannon-Wiener (H') diversity index showed that the hot pepper ecosystem had low to moderate diversity, which had increased from initial planting to harvest. The species evenness index (E) was depressed in the vegetative growth stage and increased became unstable in reproductive and harvest stages. Simpson's dominance index (D) decreased along with increasing diversity, from the medium to the low. The role of natural enemies, especially the parasitoid *M. sexmaculatus* needed to be increased to suppress the key pest population.

Funding statement. We would like to declare that the research of this manuscript was funded by the DIPA 2020 of the Indonesian Vegetable Research Institute (IVEGRI), Indonesian Agency for Agricultural Research and Development, Ministry of Agricultural of the Republic of Indonesia (Grant number: 1804.409.001.051.B).

Acknowledgements. We thank to Prof. Dr. B. M. Shepard (Professor Emeritus in Clemson University, South Carolina, United States) and Prof. Kazuki Tsuji (Laboratory of Subtropical Zoology, Department of Environmental Sciences and Technology, Faculty of Agriculture, University of the Ryukyus, Japan) for valuable comments and corrected English grammar of the manuscript.

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