Incidence and diversity of insect pests and their natural enemies in control threshold-based cabbage cultivation

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Abstract. Insect pests are a biotic factor that becomes an obstacle in cabbage cultivation. Insect diversity in cabbage ecosystem plays an important role in pest management. This study aimed to determine the diversity and structure of insect communities in cabbage ecosystem. The study was conducted at the Margahayu Experimental Garden, Indonesian Vegetable Research Institute at Lembang (1,250 masl), Indonesia from March to May 2018. Observations were made weekly on cabbage plants and on light traps. The results showed that the insects found in cabbage ecosystem belonged to the Order of Lepidoptera (four families), Homoptera (one family), Hymenoptera (one family) and Coleoptera (one family). Altogether it consisted of 11 species and 11,341 individuals that divided into 96.1-98.3% as phytophagous and the remaining 2.5% parasitoid and predator. The Shannon-Wiener (H') diversity index showed that the cabbage ecosystem had moderate diversity, which decreased from pre-heading to heading stage of cabbage growth. The species evenness index (E) was unstable in the first two months, subsequently under pressure in the last month. Simpson's dominance index (D) tended to increase, in line with decreasing diversity, although it was still in the low dominance category. The role of natural enemies, especially the parasitoid *Diadegma semiclausum*, needed to be increased to suppress the key pest population of *Plutella xylostella.*

Key Words: cruciferous crops, phytophagous, beneficial insect, abundance, dominance.

Introduction. Cabbage, *Brassica oleracea* var capitata is one of the most important cruciferous vegetables in Indonesia and worldwide, because cabbage is a source of vitamins (C, A, B1, B6, B9 and E), minerals, dietary fiber and phytochemicals (Dias 2012). The Central Bureau of Statistics and Directorate General of Horticulture reported that in 2018 the harvest area of cabbage was reached 66,110 hectares with 1,407,930 tons of production and 21.3 tons ha^{-1} of productivity. Beside used for domestic supply, cabbage in Indonesia is also exported to Japan, Malaysia, Taiwan, Singapore and the United Arab Emirates (Central Statistics Agency and Directorate General of Horticulture 2019). The export volume has increased since 2013 and in 2018 reached 24,600 tons. To increase exports, it is necessary to increase the national cabbage production with high-quality product, while in its cultivation faced with pests that can reduce production and quality.

Insect pest is a biotic factor that becomes an obstacle in cabbage cultivation. Among the pests that attack, pests from the Lepidoptera order are the most commonly found in various countries. *Plutella xylostella*, *Crocidolomia pavonana* and *Spodoptera litura* are reported as the most damaging pests and collectively are able causing damage up to 100% (Supartha et al 2014; Sireesha et al 2014; Jiang et al 2015; Stanikzi & Thakur 2016; Asikin 2017; Khan & Talukder 2017; Ahmad et al 2018; Zhu et al 2018). These conditions force farmers to use insecticides to control them. In addition, *Brevicoryne brassicae* is also reported as a pest of cabbage by Embaby & Lotfy (2015) and was able to cause damage of 7.59%. Razaq et al (2014) and Jabran et al (2016) reported that *B. brassicae* attacked canola and reduced yield up to 30%.

Dadang et al (2011) reported that 70% of farmers use 25-30% of production inputs for the cost of controlling cabbage pests, while Machekano et al (2017) also stated that in South Africa 75-100% of farmers used insecticides three times per week. Intensive use of insecticides has negative impacts on humans and animals, contamination of water, air and soil, insecticide residues in agricultural products, high persistence of insecticides in the environment, pest resistance and negative impacts on useful insects (Kandagal & Khetagoudar 2013).

Implementation of control threshold is one of methods to suppress application of insecticide. Result of research by Sastrosiswojo et al (2001) showed that implementation of control threshold of *P. xylostella* and *C. pavonana* was able to reduce application of insecticide by 82%. Prabaningrum et al (2019) reported that to control *P. xylostella*, implementation of control threshold based on the catch of moths using sex pheromone could reduce application of insecticide by 33.33%.

With global climate change, air temperatures have increased and have an impact on increasing pest insect populations, making cabbage ecosystems increasingly unstable. As a result, pest outbreaks more often occur. Therefore we need a pest management strategy that considers ecological and biological aspects of pests (Syarief & Tripama 2017). This study aimed to determine the diversity and structure of insects community in cabbage ecosystem that implement control threshold of key pests. By knowing the diversity and structure of insects community of cabbage ecosystem, pest management strategies can be developed that are able to maintain pest populations below the control threshold.

The aim of the present study is to contribute with information concerning the balance between pests and natural enemies, which is useful for improving control strategies.

Material and Method. The study was conducted at the Margahayu Experimental Garden at Lembang, West Bandung, West Java, Indonesia from March to July 2018. The experiment was carried out on a cabbage plantation with the size of 612 m^2. Six observation plots were made with the size of 102 m^2 and consisted of 220 plants. In each of the observation plots one light trap was installed five days after planting, to trap the insect pests and natural enemies.

Green Coronet variety of cabbage was grown using basic fertilizers that were applied at seven days before planting: chicken manure 15 t ha^{-1}, ZA 120 kg ha^{-1}, Urea 55 kg ha^{-1}, SP 36 250 kg ha^{-1} and KCl 200 kg ha^{-1}. Additional fertilizers were applied at 30 days after transplanting: Urea 55 kg ha^{-1} and ZA of 120 kg ha^{-1}.

Observations on 10 plants per plot were started at 14 days after planting with a week interval to count population of insects (eggs, larvae, nymphs or pupae). Observation of the imago in the light traps was done twice a week, started at seven days after planting. If control threshold for *P. xylostella* (0.5 larvae $plant^{-1}$) or *C. pavonana* (0.3 egg masses $plant^{-1}$) reached, the cabbage plants were sprayed with selective insecticide emamectin benzoate.

Insect identification and data analysis. Insects observed in cabbage plants and caught in light traps were counted and separated according to species. Identification was carried out using insect identification keys by Borror et al (1976) and Kalshoven (1981).

Abundance, diversity, evenness and dominance of the insects were analyzed.

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

$$RA = \frac{n}{N} \times 100\%$$

RA = Relative abundance
n = Number of individual insects
N = Total number of insects

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

$$H' = \sum_{i=1}^{S} Pi \ln Pi$$

H'	=	Shannon-Wiener diversity index
Pi	=	Comparison of proportions to i
S	=	Number of species found

Classification of Shannon-Wiener diversity index values:

Shannon-Wiener index value	Category
< 1	Low species diversity, low distribution of individuals per species and low community stability
1 - 3	Medium species diversity, distribution of the number of individuals of each species is moderate and 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 high

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

$$E = \frac{H'}{H_{maks}}$$

E	=	Evenness index
H'	=	Shannon-Wiener diversity index
H maks	=	Ln S (S = Number of species found)

Classification of evenness index values (Odum 1971):

Evenness index value	Category
0 < E ≤ 0.5	Depressed community
0.5 < E ≤ 0.75	Unstable community
0.75 < E ≤ 1	Stable community

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

$$C = \sum_{i=1}^{S} (Pi)^2$$

C	=	Dominance index
Pi	=	Comparison of insect proportions to i
S	=	Number of insect species found

Classification of dominance index values (Simpson 1949 cited in Odum 1971):

Dominance index value	Category
0 < C ≤ 0.5	Low dominance
0.5 < C ≤ 0.75	Medium dominance
0.75 < C ≤ 1	High dominance

Results and Discussion

Species abundance. Insects found during planting period of cabbage belong to the order Lepidoptera, Homoptera, Hymenoptera, and Coleoptera (Table 1). Insects of the order Lepidoptera consisted of four families, while the other orders consisted of one family and as a whole consisted of 11 species. All species were found in pre-heading, cupping and heading phase of cabbage growth.

Table 1

Insects found in cabbage ecosystem

Cabbage stage	*Order*	*Family*	*Species*	*Category*
Pre-heading	Lepidoptera	Plutelidae	*Plutella xylostella*	Phytophagous
		Pyralidae	*Crocidolomia binotalis*	Phytophagous
		Noctuidae	*Spodoptera litura*	Phytophagous
		Noctuidae	*Spodoptera exigua*	Phytophagous
		Noctuidae	*Plusia chalcites*	Phytophagous
		Noctuidae	*Agrotis ipsilon*	Phytophagous
		Noctuidae	*Helicoverpa armigera*	Phytophagous
		Gelechiidae	*Phthorimae operculella*	Phytophagous
	Homoptera	Aphididae	*Brevicoryne brassicae*	Phytophagous
	Hymenoptera	Ichneumonidae	*Diadegma semiclausum*	Parasitoid
	Coleoptera	Staphylinidae	*Paederus fuscipes*	Predator
Cupping	Lepidoptera	Plutelidae	*Plutella xylostella*	Phytophagous
		Pyralidae	*Crocidolomia binotalis*	Phytophagous
		Noctuidae	*Spodoptera litura*	Phytophagous
		Noctuidae	*Spodoptera exigua*	Phytophagous
		Noctuidae	*Plusia chalcites*	Phytophagous
		Noctuidae	*Agrotis ipsilon*	Phytophagous
		Noctuidae	*Helicoverpa armigera*	Phytophagous
		Gelechiidae	*Phthorimae operculella*	Phytophagous
	Homoptera	Aphididae	*Brevicoryne brassicae*	Phytophagous
	Hymenoptera	Ichneumonidae	*Diadegma semiclausum*	Parasitoid
	Coleoptera	Staphylinidae	*Paederus fuscipes*	Predator
Heading	Lepidoptera	Plutelidae	*Plutella xylostella*	Phytophagous
		Pyralidae	*Crocidolomia binotalis*	Phytophagous
		Noctuidae	*Spodoptera litura*	Phytophagous
		Noctuidae	*Spodoptera exigua*	Phytophagous
		Noctuidae	*Plusia chalcites*	Phytophagous
		Noctuidae	*Agrotis ipsilon*	Phytophagous
		Noctuidae	*Helicoverpa armigera*	Phytophagous
		Gelechiidae	*Phthorimae operculella*	Phytophagous
	Homoptera	Aphididae	*Brevicoryne brassicae*	Phytophagous
	Hymenoptera	Ichneumonidae	*Diadegma semiclausum*	Parasitoid
	Coleoptera	Staphylinidae	*Paederus fuscipes*	Predator

Figure 1 showed that most of the insects (96.1-98.3%) were categorized as phytophagous, while 0.4-0.7% as parasitoid and 2.2-3.2% as predator. The similar condition was reported by Bhat (2018) which stated that insect pests dominated the cabbage ecosystem.

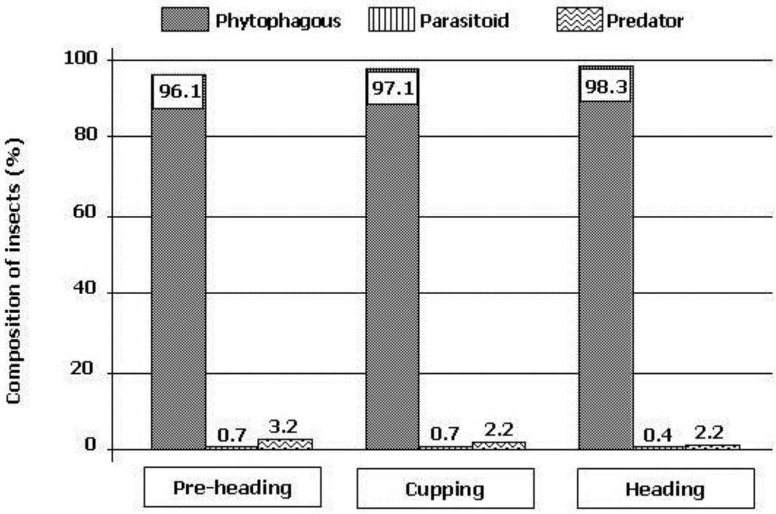

Figure 1. Composition of insects found in cabbage ecosystem.

Among the phytophagous or pests found, the abundance of *P. xylostella* species was the highest by 41.9-66.9%, followed by *Spodoptera exigua* at 18-32% and *C. pavonana* at 7.2-10.3%. While other species below 10% (Figure 2). *P. xylostella* is the main pest of cabbage in Indonesia, which attacks various cruciferae plants (Asriani et al 2013; Yuliadhi et al 2015; Sembiring 2017). It was reasonable that in this experiment its relative abundance was the highest compared with other species. In the experiment appeared that *S. exigua* was able to replace *C. pavonana* which as one of the two key pests of cabbage in Indonesia with *P. xylostella* (Yuliadhi & Sudiarta 2012). *S. exigua* is polyphagic, and one of its hosts is cabbage (Kaur & Kang 2014). The results of Azidah & Sofian-Azirun's research (2006a,b) showed that the number of *S. exigua* eggs bred using onion plants was more than using cabbage. It showed that cabbage is not the main host of *S. exigua*. Allegedly *S. exigua* found in this study originated from the existing garlic plantations around the experimental site.

The other polyphagous insects that are not pests of cabbage were *P. operculella* and *H. armigera.* They came from potato and tomato cultivated around the experiment site and attracted by the light trap.

D. semiclausum (= *D. eucerophaga*) is a parasitoid of cabbage leaf caterpillars that entered Indonesia in the 1950s from New Zealand. Sudarwohadi & Eveleens (1977) cited in Sastrosiswojo et al (2001) reported that the parasitoid had settled with an average capacity of 60-80%.

Furthermore Sastrosiswojo et al (2001) reported that the parasitism to DBM in cabbage cultivated by IPM reached 50%. The excessive use of non-selective insecticides may cause the decline of the parasitoid population. *P. fuscipes* is an egg-eating predator and attacks polyphagic moths. Its role in suppressing pest insect populations is less visible (Kalshoven 1981).

Population fluctuation of *P. xylostella* and *C. pavonana* as key pests of cabbage is presented in Figure 3, and shows that *P. xylostella* had two peaks, at 35 and 77 days after transplanting. According to Asriani et al (2013), the diamondback moth reached the peak population at eight weeks after transplanting, and cabbage-head caterpillar population increased until 10 weeks after transplanting. The high population of diamondback moth was able to suppress cabbage-head caterpillar.

There were five applications of insecticide emamectin benzoat in the present experiment, because the control threshold of *P. xylostella* was reached at 14, 35, 63, 70, and 77 days after transplanting. Yang et al (2017) reported that emamectin benzoate was an insecticide with low toxicity, low residue, low environmental pollution and was not harmful to beneficial insects. But, the pesticide drifts from around the experiment site might have responsible for the low population of *D. semiclausum* in the cabbage ecosystem.

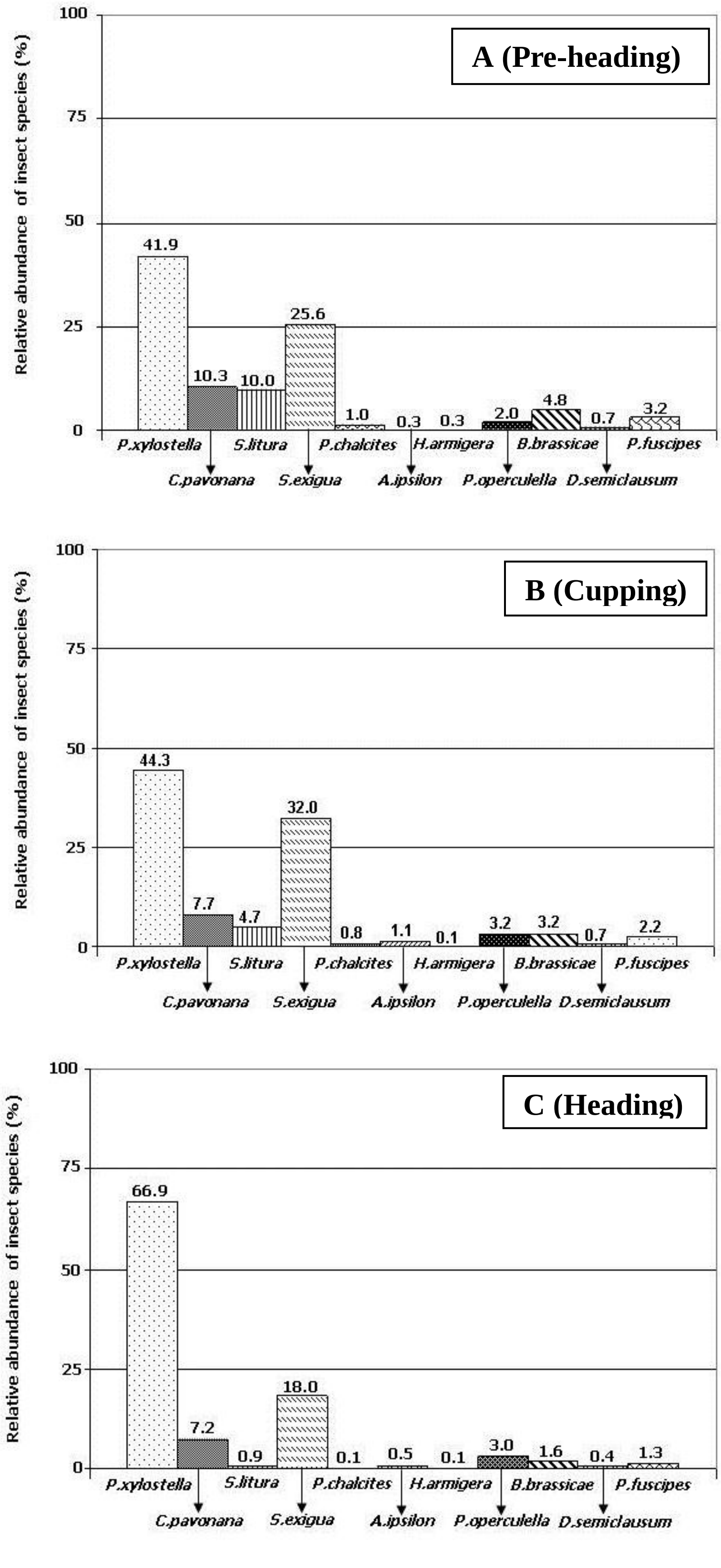

Figure 2. Relative abundance of insect species on planting period of cabbage.

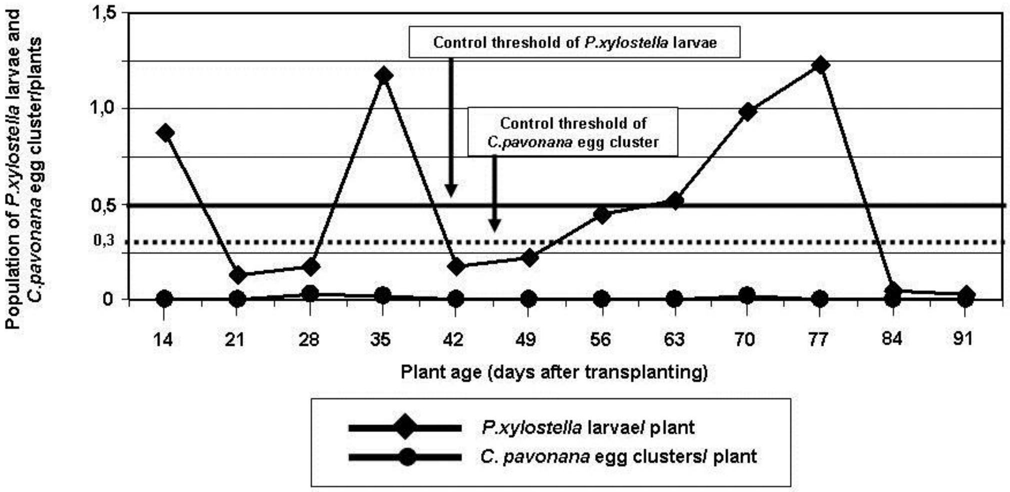

Figure 3. Population fluctuation of *Plutella xylostella* larvae and *Crocidolomia pavonana* egg clusters.

Species diversity. Cabbage ecosystem diversity from the beginning of planting to harvest time has decreased, although still in the range of moderate diversity (H '= 1.1 to 1.6). The evenness index (E) showed that in the first two months, the insects community was unstable (E = 0.6 to 0.7) and in the third month it was depressed (E = 0.5). While the dominance index C indicated a gradual increase, although it was still in the low dominance category (Table 2).

Table 2

Number of insect individuals caught, Shannon-Wiener index (H '), evenness index (E) and Simpson’s dominance index (C) during cabbage planting period

Cabbage stage	*Insect caught (individuals)*	*Shannon-Wiener index (H’)*	*Evenness index (E)*	*Simpson’s dominance index (C)*
Pre-heading	1,870	1.6	0.7	0.3
Cupping	3,783	1.5	0.6	0.3
Heading	5,688	1.1	0.5	0.5
During planting period	11,341	1.36	0.6	0.37

The three parameters of diversity indicated were similar with generally agricultural ecosystems; the cabbage ecosystem was unstable and allowed a surge in pest populations. It might have happened because the natural enemy population was too low which was unable to suppress the key pest population. The insect’s community in cabbage ecosystem was dominated by *P. xylostella.* The very low population of *D. semiclausum* was unable to suppress population of the cabbage leaf caterpillar. Syarif et al (2018) reported that the use of insecticides would kill natural enemies so that they were unable to control herbivores.

Controlling pests population can be done by increasing plant diversity, such as intercropping. Mochiah et al (2011) had proven that intercropping of cabbage with tomato was able to suppress population of aphid, whitefly, grasshoppers, cut worm and diamondback moth on cabbage. It would be difficult to the pests to find their host plants in intercropping system.

To increase the role of natural enemies, efforts should be made to suppress the use of insecticides in various ways. Li et al (2019) reported that the implementation of control threshold was proven to be effective in reducing insecticide spraying by up to 50%. In addition, the provision of flowering plants to attract parasitoids is also effective in increasing the role of natural enemies. Htun et al (2011) reported that planting

Dendranthema in cabbage cultivation could provide a place for the parasitoid *Cotesia plutellae*. Sepe & Djafar (2018) used refugia plants and cabbage in intercropping system for increasing species diversity and population of parasitoids.

Conclusions. The results of this study indicated that the insects found in the cabbage cultivation belong to the Order Lepidoptera (four families), Homoptera (one family), Hymenoptera (one family) and Coleoptera (one family). Altogether it consisted of 11 species and 11,341 individuals divided into 97.5% as pests and the remaining 2.5% parasitoid and predator. The Shannon-Wiener (H') diversity index showed that the cabbage ecosystem had moderate diversity, which had decreased from initial planting to harvest. The species evenness index (E) was unstable in the first two months, subsequently under pressured in the last month. Simpson's dominance index (D) tended to increase, in line with decreasing diversity, although it was still in the low dominance category. The role of natural enemies, especially the parasitoid *D. semiclausum,* needed to be increased to suppress the key pest population of *P. xylostella.*

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