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Population dynamics of *Zeuzera* spp. (Lepidoptera: Cossidae) on *Eucalyptus pellita* plantation in Central Kalimantan, Indonesia

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Abstract. *Suheri M, Haneda NF, Anwar R, Jung Y, Sukeno S, Park J. 2022. Population dynamics of* Zeuzera *spp. (Lepidoptera: Cossidae) on* Eucalyptus pellita *plantation in Central Kalimantan, Indonesia. Biodiversitas 23: 5782-5789.* The red coffee borer, *Zeuzera* spp. (Lepidoptera: Cossidae) damage to *Eucalyptus pellita* forests was one of the problems in the forestry sector. The population dynamic of these insects is monitored and surveyed on *E. pellita* at PT Korintiga Hutani. The present study aimed to analyze the contributing factors of *Zeuzera* spp. damage to *E. pellita* plantation and observe the population dynamics of *Zeuzera* spp. using pheromone traps. The survey results showed that the accumulated damage in planting block 5 was more serious (29%) than in planting block 6 (9%). The impact of the multi-regression analysis indicates that the main factors affecting the damage are the location and age of the plantation. At the same time, the *E. pellita* clonal difference is minor compared to those two factors. The damage is more severe and occurs at an older age of plantations. The population dynamics of *Zeuzera* spp. observed in *E. pellita* plantation showed a peak flight trend in October, followed by a reasonably high population presence from late May to early June. This information could be a primary consideration for these insect pest need to control the significant damage to *E. pellita* trees and determine the management of *Zeuzera* spp. based on the timing of larvae infestation in the upcoming after-peak flight.

Keywords: Monitoring, pheromone trap, peak flight, stem borer, trend

INTRODUCTION

The development of industrial plantation forests has been carried out since 1960 in Pangkalan Bun, Central Kalimantan, Indonesia with the current main species *of Eucalyptus pellita* and *Acacia mangium*, which cover 93% of the total forest area (Lumbres et al. 2015). *Eucalyptus pellita* is a major commodity because of its fast growth (Lukmandaru 2018). Moreover, widely used for pulp and paper materials (Herawan and Leksono 2018), this plant was used for the manufacture of bio pellets (Iswanto et al. 2021). In addition, this plant is used for essential oils, medicines, charcoal raw materials, and honey bee cultivation sites (apiculture)) (Adinugraha et al. 2016). In contrast, stem borer, *Zeuzera* spp. group (Lepidoptera: Cossidae) attack and cause damage that can decrease productivity.

Zeuzera spp. is a group of moths in phase larvae as stem borers on their host plants (Suheri et al. 2020). The initial damage begins when the larvae hatch directly, look for young shoots and branches to enter, then damage from the inside (Monteys 2015). The insect attack causes the host plant to wither and die (Almanoufi et al. 2012). Recently climate change has made things worse for trees with severe damage (Fekrat and Farashi 2022). Host plants have been damaged by *Zeuzera* spp. and when heavy damage to plants occurs, fruit productivity and growth decrease (Sunitha et al. 2022). One species of stem borer *Zeuzera*, *Z. coffeae* has been considered one important pest for tea and coffee plantations in India with serious damage (Samikska 2017). *Zeuzera coffeae* and other species of stem borer have become important pests on sandalwood (*Santalum album*) in India. They make holes in stems so that the economic value of that wood is lower (Sundararaj 2019). The damage to the trees and population dynamics of *Zeuzera* spp. on *E. pellita* plantations in Indonesia has not been further observed, so monitoring activities are needed to be determined for future management steps.

Monitoring is one of the principles of integrated pest management (Arnaudov et al. 2012). Identification of insects and other pests will be monitored regularly so that the management strategy of pests becomes more appropriate (Sutrisno 2015). Results of monitoring show that there are many plant hosts of these insects, including okra (*Abelmoschus esculentus*), tea (*Camellia sinensis*), chestnuts (*Castanea* sp.), cinnamon (*Cinnamomum verum*), wampi (*Clausena lansium*), leucaena (*Leucaena leucocephala*), cotton (*Gossypium* sp.), avocado (*Persea Americana*), indian sandalwood (*Santalum album*), teak (*Tectona grandis*), breadfruit trees (*Artocarpus* sp.), hickories (*Carya* sp.), kapok (*Ceiba pentandra*), citrus (*Citrus* sp. (citrus), coffee (*Coffea* sp.), walnut (*Juglans regia*), cassava (*Manihot esculenta*), poplars (*Populus* sp.), mahogany (*Swietenia* sp.), and cocoa (*Theobroma cacao*) (PKB 2017). Integration of various pest controls is reported to provide optimal results (Fitri et al. 2020). Integration of mechanical, chemical, and biological control on the walnut orchard in Pakistan succeeded in controlling *Zeuzera* spp. (Ahmad 2017). Using odonil oil on holes in the stem of plants reduces 55% population of *Zeuzera* spp. However, the method was not applicable due to extensive damage (Gupta and Tara 2014). Sanitation, selection of healthy plants, mechanical, and biological sampling material and agro chemistry may be applied for controlling *Zeuzera* spp. Selective insecticide such as imidacloprid is sometimes used for this species (Shrestha and Thapa 2015).

The management of this pest has been challenged because the most prolonged phase was inside the host-plant stem. One alternative to monitoring is to use pheromone traps and surveys of their damage. Pheromone traps have been used in some cases, such as *Z. pyirina* in Apulia (Southern Italy) (Guario et al. 2002), control *Z. pyrina* with differences in size and color trap in Iran (Ardeh et al. 2014), its use for *Z. pyrina* in a walnut orchard (Rohani and Samih 2012), intial monitoring in *E. pellita* (Suheri et al. 2020), and control *Z. pyrina* on olive (*Olea europea* L.) orchard (Hegazi et al. 2015). Damage monitoring can be done by surveying several sampling sites to determine actual conditions in the field. This activity can be a method of understanding the damage and dynamics of insect pest populations in the forest (Fischbein and Corley 2022). This study investigated the factors contributing to the damage of *Zeuzera* spp. on *E. pellita* plantations and observed the population dynamics of *Zeuzera* spp. using pheromone traps.

MATERIALS AND METHODS

Study area

This research was conducted at Perizinan Berusaha Pemanfaatan Hutan (PBPH) PT Korintiga Hutani (PT KTH), Central Kalimantan, Indonesia. PT KTH is a private forest plantation company with the main species of tree, *E. pellita*. The survey location was carried out in block 5 and block 6 based on the results of initial damage monitoring with an age range from 3 months - 3 years, for as many as 127 plots. The installation of pheromone traps was carried out in 85 sites based on the severity of the survey results. Preparation, data collection, and procession were carried out at camp pellita (Figure 1).

Procedures

Zeuzera spp. damage survey

The survey was carried out in block 5 and block 6 *E. pellita* plantation of PT Korintiga Hutani with a purposive sampling method based on initial observations with a total of 127 plots. The survey method used transects 5-5, with the starting point of observation from the plot's middle or corner. Checked five trees in a row, moved five rows toward the right-hand side and checked 5 trees in the row. Repeat this process until the end of the compartment border. The minimum number of trees to survey is 300 trees/compartment. (Figure 2). The variables and indicators observed were symptoms of plant attack by *Zeuzera* spp. (swollen stem, frass, broken top crown, fork stem), stem form, and diameter (DBH) for Clone 170 and ID_063. The information obtained in the survey activities is the incidence of damage (Rahayu et al. 2021), accumulated damage of each clone of *E. pellita*, and grouping of compartments by damage category.

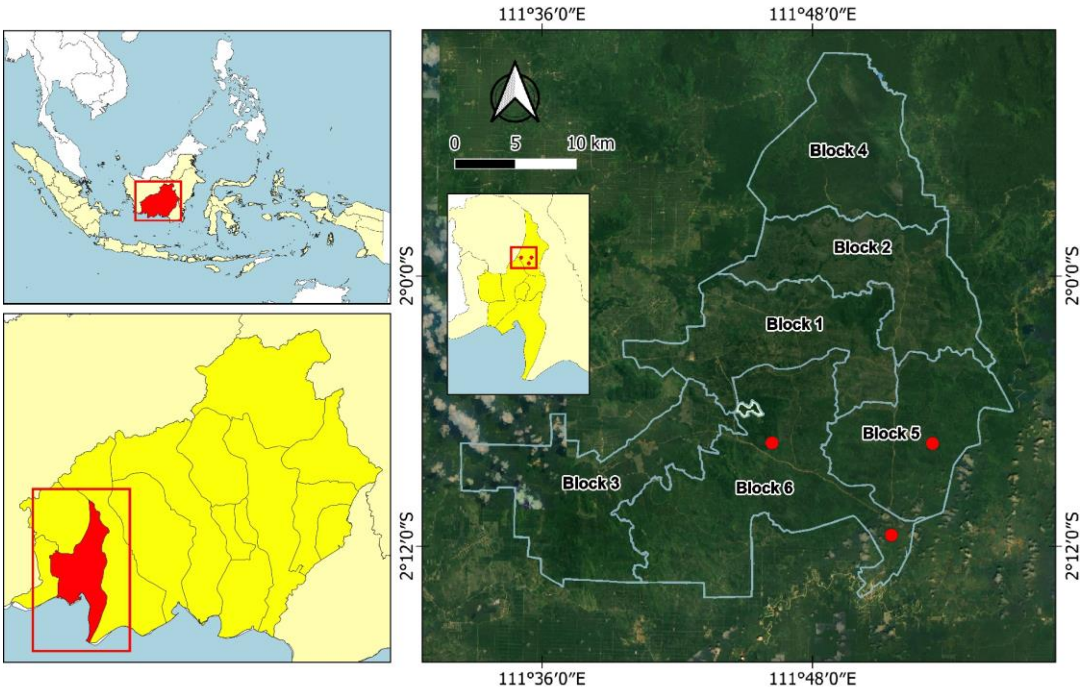

Figure 1. Research location at PT Korintiga Hutani camp pellita (111^{0} 51’ 29.859’’-2^{0} 11’29.814’’), block 5 (111^{0} 53’19.078’’ -2^{0} 7’ 25. 777’’), and block 6 (111^{0} 46’ 12.548’’ -2^{0} 7’ 24.284’’)

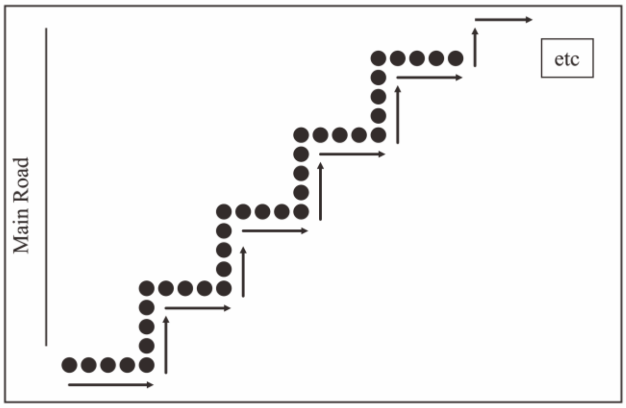

Figure 2. Illustration of *Zeuzera* spp. damage incidence survey on *E. pellita* trees

Percentage of *Zeuzera* spp. damage incidence = (n/N) x 100%

Where:
n : the number of trees with damage
N : total number of trees observed

Pheromone trap installation

The installation of pheromone traps was carried out from May 2019 to April 2022 on 85 plots based on information from monitoring results with severe damage to selected locations. The trap used is a type of delta trap with a dimension of 26 x 20 x 11 cm. Pheromone trap lures were accessed from Pherobio's company in China (Suheri et al. 2020). Observations were carried out weekly by checking the number of caught moths and the condition of the sticky card that was replaced when it was full of caught moths or could not stick. Mouse glue is used to make it more adhesive and durable. The change of pheromone trap rules was carried out once every two months. The data obtained were the accumulative number and increase of adult insects every week (Suheri and Haneda 2019).

$$\Delta Z = (B - A)$$

Where:
ΔZ : The number of adult insect catches increases every week each plot
B : The number of catches this week
A : Number of catches last week

Data analysis

Multiple regression analysis on the *Zeuzera* spp. damage rate using age of trees, block, and clone of *E. pellita* as factors was determined using SPSS version 23. At the same time, the processing of monitoring pheromone traps data was done using Microsoft excel version 2013.

RESULTS AND DISCUSSION

Results

The survey results showed that the insect damage occurs in block 5 was more serious (29%) than those in block 6 (9%) (in terms of the damage by *Zeuzera* spp.; swelling, holing, and forking stem). It can be determined from the symptoms and signs on the trees observed at the block 5 location, which show more damage by *Zeuzera* spp. in the survey. The results of monitoring in block 5 sites were known that the average survival rate of trees is 88%, while in block 6, it is 90%. Moderate symptoms occur in block 5, including a tree with a hole on the stem (6%), a tree with swelling on the stem (17%), and trees with a fork stem (12%). Block 6 site had average symptoms of a tree with a hole on the stem (3%), a tree with swelling on the stem (5%), and a tree with a fork stem (3%). The accumulation of tree damage (only one symptom of fork stem or swollen stem) in block 5 had an average of 29%, with an average of crooked trees (6%). The average category of deformed trees (a combination of *Zeuzera* spp. damage and crooked trees) is 37%. Block 6 with accumulated damage of 9%, with an average crooked tree of 6%, so the category of deformed trees is 16%. The result summary of the *Zeuzera* sp damage survey in block 5 and block 6 is presented in Table 1.

Table 1. Summary of the results of the *Zeuzera* spp. damage survey in block 5 and block 6

Block	Clone	No of plot	Age (yr)	Survival rate (%)	*Zeuzera* spp. damage				Trees with crooked stem	Defected trees**	Mean DBH (cm)
					Trees with hole	Swollen stem	Fork stem	Trees with stem damage*			
5	ID_170	7	2.0	82%	13%	16%	14%	34%	23%	55%	10.3
5	ID_27	3	2.6	84%	3%	17%	16%	33%	3%	41%	
5	ID_30	49	2.3	90%	5%	19%	12%	30%	2%	34%	
5	ID_63	12	1.9	79%	5%	12%	8%	22%	12%	38%	11.1
Mean Block 5		71	2.2	88%	6%	17%	12%	29%	6%	37%	10.8
6	ID_27	7	1.6	85%	3%	3%	3%	8%	0%	18%	
6	ID_30	20	1.4	88%	3%	6%	3%	11%	4%	19%	
6	ID_63	30	1.3	93%	3%	4%	3%	8%	8%	17%	8.1
Mean Block 6		57	1.4	90%	3%	5%	3%	9%	6%	18%	8.1
Mean		128	1.9	89%	4%	12%	8%	20%	6%	28%	9.0

Note: *: Trees with at least one of the damages (i.e. hole, swelling, broken/fork) by *Zeuzera* spp., **: Trees with *Zeuzera* damage and/or crooked stem

The results of the multi-regression analysis showed that the main factors to contribute the damage were the location and age of the plant, while the difference in clones was only slighter than the two factors. The results showed that damage correlates positively with plant age. The more severe damage was found in older plant ages (Table 2). We can see that the more mature the tree, the symptoms of damage that appear higher are holes on the stem, swollen stem, produced frass, broken top crown, and fork stem. Different conditions of young plants were still difficult to detect the presence of symptoms and signs of attack *Zeuzera* spp. (Figure 3).

The clone factor shows that there is not much different susceptibility among the cloned plants to *Zeuzera* spp. attacks. Each damaged clone data had the highest average on Clone ID_170 (33%), followed by ID_30 (24%), then ID_27 (16%), EP_BENIH (14%), and finally ID_063 (12%) (Table 3). This result made an evaluation to carry out tree improvement activities, not only increasing wood productivity, but also more resistant to pest attacks, one of which is *Zeuzera* spp. stem borer.

The accumulation of damaged plants by *Zeuzera* spp. in block 5 and block 6 are divided into four groups based on the incidence and severity assessed by each plot (Table 4). The red color group is indicated as a category of severe damage (more than 25%) with 44 plots. The orange group is a severe category (15%-25%) with 39 plots. The green group of the moderate severity category (8%-14%) with 19 plots. The yellow group with a class of minor severity (less than 8%) with 35 plots.

Table 2. Multiple-regression analysis on the *Zeuzera* spp. damage rate by using age, block, and clone as a factor

Model	Non-standardized coefficients		Standardization factor	t-value	P	Correlation			Multicollinearity statistics	
	B	Standard error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(constant)	15.242	6.052		2.518	.013					
ID170	6.702	4.892	.097	1.370	.173	.213	.123	.093	.915	1.093
ID27	-2.349	4.215	-.040	-.557	.578	-.084	-.050	-.038	.885	1.130
ID63	-2.678	2.657	-.080	-1.008	.315	-.347	-.091	-.069	.728	1.374
BLK6	-12.667	3.168	-.402	-3.999	.0001	-.625	-.340	-.272	.457	2.189
Age (yr)	6.028	2.518	.239	2.394	.018	.557	.212	.163	.463	2.161

Note: Dependent variable rate of the damaged tree (%)

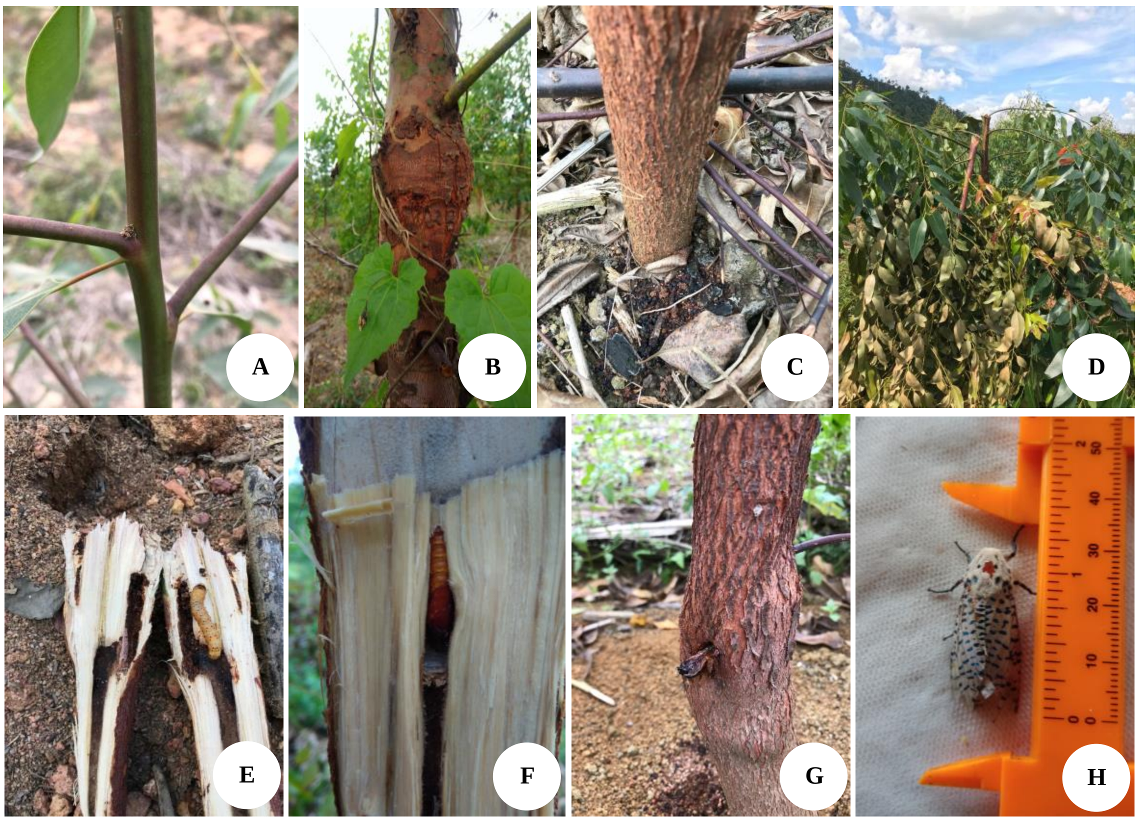

Figure 3. A. The initial damaged plants of *Zeuzera* spp. on *E. pellita* with an age of 3 months, B. The trees with swollen stem, C. Produced frass, D. Broken top-crown, E. Cross-sectional damage stem of *E. pellita* by larvae of *Zeuzera* spp., F. Pupae phase, G. Imago of *Zeuzera* spp. emerge from pupae by splitting the pupal case, H. Imago of *Zeuzera* spp.

Table 3. Degree of damage *by Zeuzera* spp. based on clone *E. Pellita*

Clone	Age (yr)	Survival rate	Traces of damage	Swollen stem	Broken top crown & Fork stem	Total damage	DBH (cm)	Bented rate
EP_BENIH	1.7	94%	2%	14%	1%	14%		
ID_170	2.0	84%	13%	15%	14%	33%	10.5	26%
ID_27	1.9	85%	3%	7%	7%	16%		4%
ID_30	2.1	90%	4%	15%	9%	24%		9%
ID_63	1.5	90%	3%	6%	4%	12%	8.7	10%
Mean	1.9	89%	4%	12%	8%	20%	8.9	11%

Table 4. Degree of *Zeuzera* spp. damage on each compartment of *E. pellita*

No	Group	Severity of damage (%)	Damage categories	N (Compartment)
1		> 25	Very severe	44
2		15 ~25	Severe	39
3		8 ~15	Moderate	19
4		0 ~ 8	Minor	35

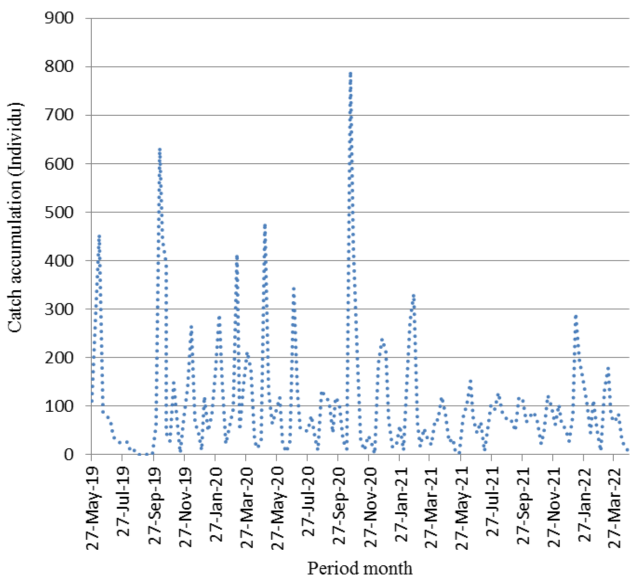

Figure 4. *Zeuzera* spp. imago catch using a pheromone trap for the period May 2019 - April 2022

Monitoring pheromone traps from 2019 to early 2022 obtained fluctuating flight data. From late May to early June 2019, captured adult insects were relatively high (563 male adults), and then the population dropped every month. Then the population increased significantly in October 2019 (1469 male adults). In early March 2020, the increase was relatively high (414 male adults), followed by May 2020 (610 male adults). The highest peak occurred again in October 2020 (1265 male adults). Furthermore, the captured adult insects were relatively high in February 2021 (331 male adults), then the population decreased until early 2022 (Figure 4.)

Discussion

Monitoring activities are vital in monitoring the presence of insect pests in a forest ecosystem for decision-making in its management (Choi and Park 2019). The damage to *E. pellita* by *Zeuzer*a spp. depends on the survey that provides factual information that these insects threaten the development of plantation forests. The damage to the traces of the rims on the *E. pellit*a borer after 3 years was examined through split logs. There was no tree showing recovery (when the log is split, the tunneling stem is still extant). In accordance with Tavares et al. (2020), the insect *Z. coffeae* causes damage to *E. pellita* by eating the stem so that it becomes hollow and damaged. In addition, the position of the larvae feeding by following the trunk circle causes the stem to break easily. In the windy season, there are many phenomena of the broken top crown in the field, which prove that *Zeuzera* spp. attacks still exist. According to Yulianto (2007), some trees that are attacked by *Z. coffeae* will easily collapse because the trunk has been damaged inside. One of the signs that *E.pellita* have *Zeuzera* spp. damage was that frass could be found in the vicinity of a tree. Frass is feces resulting from the activity of larvae eating round rods like pellets. Usually, the size of the frass can be the initial phase indicator and the size of the insect. Frass will increase in size as the larvae's instar grows and changes. The condition of the frass, which is still new with a red-brown color, indicates that the larvae are still actively bored. Frass that has begun to dry with a red-brown-black color suggests that the insect has started in the pupal phase. According to Lestari and Purnomo (2018), one of the things that can be noticed when trees experience an attack by *Z. coffeae* is the release of red-black frass from the burrows of the borer.

Different locations have different incidences of damage by the same insect pests. There was a difference in the total damage in observation sites, blocks 5 and 6. The disparity damage between blocks 5 and 6 was caused by the location's proximity to the source of the inoculum.

According to Suheri et al. (2020), early detection of *Zeuzera* spp. damage on *E. pellita* plantation in PT KTH occurred in block 4. Furthermore, insects that have finished their life cycle move to another plant nearby (block 5). The damage began to spread, and they moved to the following location, Block 6. The location of block 5 technically suffered a higher accumulation of damage than block 6 because it suffered an attack firstly. Differences in damage and diversity of insect pests can also be influenced by the presence of the structure and composition of their infiltration plants (Nurkomar et al. 2021). In addition, locations with variations in degraded forests cause differences in threats and damage that occur by insect pests (Kekeunou et al. 2006).

Symptoms and signs become indicators in the monitoring of insect pests. The selection of monitoring strategies needs to be adjusted based on the existing conditions considering the current climate change phenomenon (Skendžić et al. 2021). *Zeuzera* spp. damage survey activities show that the older the tree becomes, the more the damages appear. We can see that on older trees, the symptoms and signs will be more easily detected than on young trees. However, this was solved after we monitored damage initiation early on when the young *E. pellita* began to be attacked *by Zeuzera* spp. at 2-3 months. Young larvae begin to bore on the petiole part of the leaves. In line with the statement (Tonini et al. 1986), shortly after the larvae quickly hatch, they look for a host to live mainly on young shoots and branches, then develop to damage from within.

Tree improvement activities with clone selection tend to be resistant to pest and disease attacks are one of the methods for managing insect pests in forestry plants (Siregar et al. 2019). *E. pellita* clone conditions that show no real difference to *Zeuzera* spp. attacks need future evaluation. PT KTH seeks to improve the quality of *E. pellita* clones with a series of selections and assessments to obtain quality clones for productivity and minimal pest and disease attacks. The combination of genes of other resistant species is one of the keys to developing resistant plants (Santos et al. 2014). Based on the statement Prat and Haneda (1999), tree breeding programs are essential in developing forest plantations to produce plants resistant to the insect pest *Z. coffeae* to increase their productivity.

Zeuzera spp. population dynamics observed in *E. pellita* plantations showed a peak flight trend in October, followed by a reasonably high population in late May to early June as a continuation of Suheri et al. (2020). Hegazi et al. (2015) found two peak flight times (late April to October). At the same time, Almanoufi et al. (2012) claim that peak flights are found from May to July. There are two peak flight times for installing pheromone traps in Iran (Rohani and Samih 2012). The time difference is thought to be due to differences in the species of *Zeuzera* spp., the type of pheromone, and environmental conditions. The difference in the number of catches can also be due to differences in the kinds of traps. According to Ardeh et al. (2014), the trapezoidal trap can catch more adult insects delta trap.

Implementing the results of monitoring pheromone traps is the basis for decision-making by management in determining insect pest control. The phenomenon of peak flight found in a particular month of each year determines the occurrence of mass mating and the spread of larvae in plantations which is quite significant. This opportunity became our basis for intensive management (technical, mechanical, biological, chemical limited, and silvicultural practice) after the peak flight mass to prevent young larvae from entering the host plant and inflicting more severe damage. Based on Miluch et al. (2013), the scheme of catching adult insects using pheromones traps is a reference for detecting insect fluctuations which can be helpful in their management activities. Accurate monitoring of insect pests in an ecosystem can also be used using a pheromones trap. Based on research by Gu et al. (2013), insect monitoring *Trichophysetis cretacea* can use alternative monitoring pheromone traps. In addition, using pheromone traps helps advance the integrated management of insect pests and minimizes the application of insecticides (Knight et al. 2013).

Decreasing the number of catches was suspected that the increase in age of the host plant leads to compatibility with the larvae's life. They move to younger plants for a complete life cycle. In addition, we assume that the presence of *Zeuzera* spp. populations due to the installation of spreading pheromones influence the decline of the male population so that females produce more infertile eggs and, in the end, larval infestations decrease in the masses to come. Several location plantations around the installation of pheromone traps show damage to *Zeuzera* spp. on average below 10% (evaluation process continuing). According to Guario et al. (2002), installing the pheromone trap can significantly decrease the damage to *Zeuzera* spp. in the future. Parasitoids and predators can influence a Lepidoptera group's population abundance (Suwarno 2009). Climate change factors that are quite pronounced in the study site area with high temperatures (± 32°C) changed significantly. We thought it also affected the existence of this insect pest. According to Fekrat and Farashi (2022), climate change is a stimulant of structural change and the spread of *Zeuzera* spp. pests. Determining strategies to analyze the worst risk impacts (outbreaks) is necessary. Another factor in the number of imago *Zeuzera* spp. catches found in clones with ID_170 contributed to the highest number of catches. The population is seen to be relatively low when carrying out young trees (under one-year-old).

In conclusion, monitoring the imago *Zeuzera* spp. population using trap pheromones indicated that some peak flight times were in October, followed by a reasonably high population in late May to early June. The capture of imago *Zeuzera* spp. using pheromones is enough to reduce mating rates and impact larvae infestations in the future. Implementation after knowing the existence of peak flight trends from monitoring pheromone traps is our basis for intensive management (technical, mechanical, biological, chemical limited, and silvicultural practice). *Zeuzera* spp. damage survey on *E. pellita* plantation showed that the main factors influencing the damage were the location and age of the plant, while the difference in clones was slighter than the two factors.

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