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Research Article

The Vertical Distribution of *Helopeltis bradyi* and *Oxyopes javanus* on Tea

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ABSTRACT

Helopeltis bradyi is the main pest of tea plants. Ecological characteristics of this pest are important to be understood to support the development of their management and control measures. This study aimed to determine the coexistence and vertical distribution pattern of *H. bradyi* and its predator, *Oxyopes javanus*, on tea plant parts. The study was conducted at the PT Pagilaran tea plantation in Central Java, in the 2018 rainy season. Population observations were carried out in situ on 20 infested sample-trees taken randomly, for 10 consecutive days, in the morning, at noon, and in the afternoon. Vertical distribution patterns were determined based on Poisson dispersion index (DI), negative binomial, and Green index (GI). The results showed that the *O. javanus* spider was found preying on *H. bradyi*. Coexistence between this pest and predator in the same part of the plant, the pest, and the predator, occurred in the morning were 50.0, 42.8, and 7.2%; at noon were 58.3, 41.7, and 0%; and at the afternoon were 66.7, 33.3, and 0%, respectively. The parts of the plant for the coexistence are pekoe leaves; the 1st, 2nd, 3rd, and 4th of young leaves; and 1st of older leaves. The pattern of vertical distribution in the morning, at noon and in the afternoon for *H. bradyi* was the weak clump, while for *O. javanus* was uniform. The ratio of predator: prey in the morning, at noon and in the afternoon was 1:10.7, 1:16.7, and 1:10.0, respectively.

Keywords: coexistence, distribution pattern, *Helopeltis bradyi*, *Oxyopes javanus*, tea

INTRODUCTION

In 2013, Indonesia ranked 6th as the world's largest tea producing country with a production of 150,000 tons per year (Ramhot, 2015). However, tea production has been decreasing per year (Pusdatin, 2015). One of the causes is the presence of pests on tea plantations. *Helopeltis* was originally a minor pest in tea plantations, has been a major pest (Anonymous, 2018). The yield loss reaches 40% and the predicted loss is 50−100% (Gusti & Soesanthy, 2014). Integrated control techniques are needed to control *Helopeltis*, hence minimize the use of conventional pesticides applied to tea plants. Mechanical control and the use of natural enemies are the control techniques for pests of the tea plant, including *Helopeltis* (Hazarika *et al*., 2009). There are various kinds of natural enemies of *Helopeltis* on tea plantations, for example, predatory arthropods. The spiders as predators dominate (43%) compared to other predators. One of the genera found is *Oxyopes* (Das *et al*., 2015).

The pest distribution pattern has been widely investigated as basic information in the study of ecological characteristics and pest control management (Muraleedharan *et al*., 1988; Wagiman *et al*., 1998; Siswanto *et al*., 2008). The vertical distribution pattern of pests is important to be studied because it can affect sampling programs, describe the condition of the population, and can be used to analyze predator-prey relationships (Southwood, 1978). Predator-prey relationships are very important in agroecosystems. The characteristics of predatory behavior to the distribution of prey can be studied vertically in host plants (Wagiman *et al*., 1998). According to Siswanto *et al*. (2008), the spatial distribution pattern of *H. bradyi* is clump on cashew plants. Yet the research about the distribution pattern and coexistence between *H. bradyi* and their predators on tea plants has not been conducted. *Oxyopes javanus* spiders are found to be associated with tea plants and eat *H. theivora* in India. *O. javanus* conservation or augmentation in the tea ecosystem can provide effective biological management for *Helopeltis* (Basnet & Mukhopadhyay, 2014). Therefore, this study aimed to determine the coexistence and vertical distribution pattern of *H. bradyi* and *O. javanus* in the tea plant. This research provided basic information in an effort to control *H. bradyi*, both using mechanical technique and natural enemies.

MATERIALS AND METHODS

Research Location

This research was conducted at the PT Pagilaran, Batang, Central Java tea plantation in April 2018, by monitoring the population of *H. bradyi* and *O. javanus*. The type of tea plant in PT Pagilaran was based on age criteria: producing plants, young plants not yet produced, and young plants produce. Young plantations produce located at an altitude of 720 masl and covering an area of 4 ha were selected in this study as observation sites. This selection was based on plant structure influenced by the age of the plant and the year of crop cutting. The criteria for selected young plants were plants with the age of 10 years in the plucking status of the Jendang (first cutting year). This would make the plant structure has not many branches, twigs, and leaves (Figure 1). Based on these criteria, the condition of tea plants becomes easier to be observed visually. The sample selection was based on the existence of *H. bradyi* attack on selected tea plants. Preliminary observations were made to determine the optimal n value in sampling.

Sampling Technique

Observations were carried out visually and in situ by observed the existence of various stages of *H. bradyi* and *O. javanus* in parts of tea plants (Figure 1), which was calculated based on the number of individuals observed for each stage: eggs, nymphs, and adults were calculated as one individual. In the egg stage with the appearance of a pair of the chorion, strands were counted as one individual. If egg mass was found, then counted the number of chorion strands as the number of eggs. The number of the nymph and adult stage was calculated more easily than eggs.

Samples were taken purposively by selecting 20 plants attacked by *H. bradyi* and carried out randomly. The purposive mechanism for random sampling was that there are criteria for selecting samples (plants attacked by *H. bradyi*), hence the sampling was done purposively. If selected plants did not meet the criteria, the closest young plants that meet the criteria from selected plants were selected randomly. Observations were conducted on three categories of time: in the morning at 06.00−08.00 (Western Indonesian Time), in the noon at 11.00−13.00 (Western Indonesian Time), and in the afternoon at 16.00−18.00 (Western Indonesian Time). Ten replications

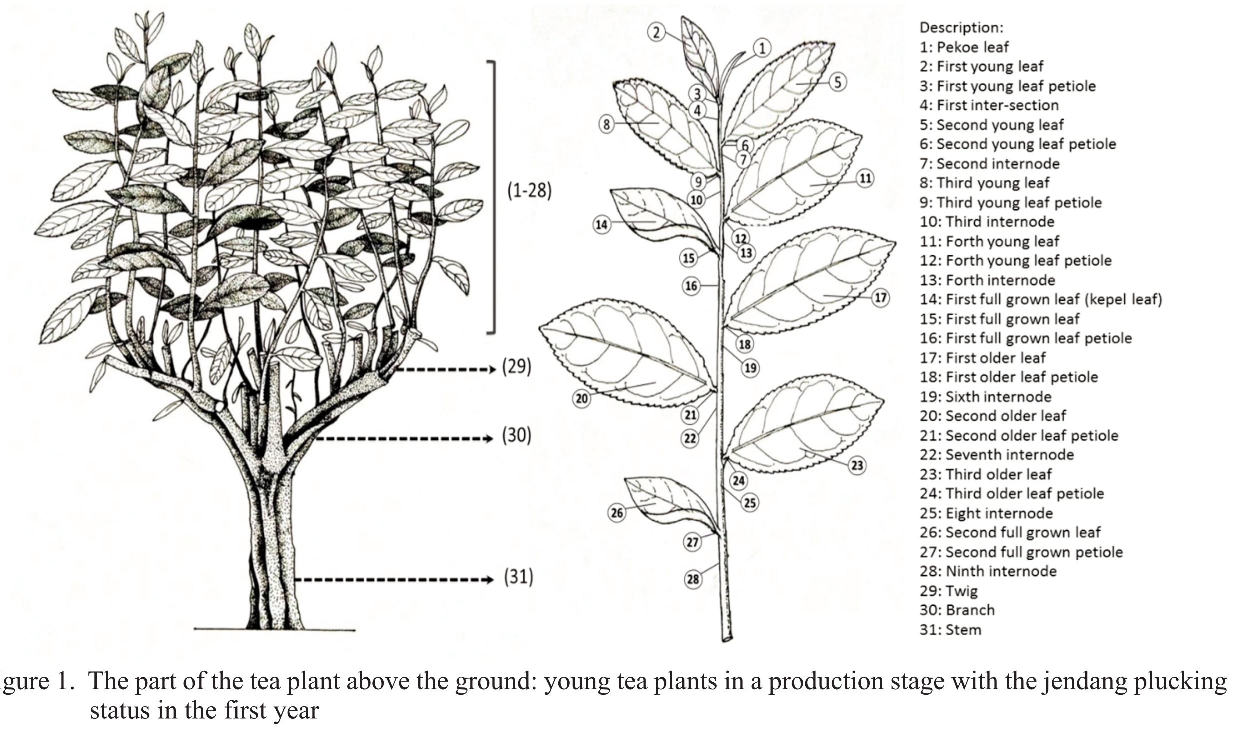

Figure 1. The part of the tea plant above the ground: young tea plants in a production stage with the jendang plucking status in the first year

were used for each observation time on a different day, without a rainy day. The sample unit used was one tea plant. Determination of optimal n was employed to determine the size of sampling. On the observing vertical distribution with purposive sampling, the character type of the sample is homogeneous thus to obtain the optimal n value using this following formula (Southwood, 1978):

$$n = \left(\frac{S}{E\,\bar{x}}\right)^2 \quad [1]$$

n = number of samples, S = standard deviation, x = average population, E = standard error. Based on the calculation of preliminary observation, the optimal n value was 20 units with a standard error of 0.16%. The parameters observed were the number of *H. bradyi* in various stages (eggs, nymphs, and adults), and the number of *O. javanus*.

Data Analysis

Data of the vertical distribution of *H. bradyi* and *O. javanus* was analyzed based on the Poisson dispersion index (DI), negative binomial ($\hat{k}$), and Green Index (GI) by Ludwig and Reynold (1998), reported that insects will form a spatial distribution pattern clump naturally. Siswanto *et al*., (2008) also stated that *Helopeltis* has a clump distribution pattern in cashew plantations. Testing of this distribution pattern was through several stages: Ho was rejected from the Poisson distribution thus the insect population was not randomly distributed, the negative binomial test was used to justify if the targeted insect population was clump distributed, and the Green index was used as a further test to determine the grouping degree of the target insect population. The three analysis was needed to conclude comprehensively and mutually as described by Ludwig and Reynold (1998).

The formula for calculating the Poisson dispersion index (Ludwig & Reynold, 1998):

$$DI = s^2/\bar{x} \quad [2]$$

The Poisson dispersion index (DI) was interpreted in the following categories: if the value of DI = 1 was random spatial distribution; DI < 1 was uniform; and if DI > 1 was clump distribution. The value of d (samples ≥ 30) or Chi-Square χ2 (samples < 30) was used to test Poisson model.

The formula of Chi-Square χ2, and d (Ludwig & Reynold, 1998):

$$X^2 = \sum_{i=1}^{n}(x_i - \bar{x}^2)/\ \bar{x} \text{ or } X^2 = \mathrm{ID} - (\mathrm{N}-1) \quad [3]$$

$$d = \sqrt{2x^2} - \sqrt{2(N-1)-1} \quad [4]$$

χ2= chi square calculation, $\bar{x}$ = average population, DI = Dispersion Index, *d* = calculated statistic value for sampling size ≥ 30; N = number of sample.

The formula for calculating a negative binomial was , if the average population is small (less than 4) then the formula used is (Ludwig & Reynold, 1998):

$$\hat{k} = \log_{10}(n/n0) = \hat{k}\ \log_{10}\left[1 + (\bar{x}/\hat{k})\right] \quad [5]$$

$\hat{k}$ = negative binomial index, $\bar{x}$ = average of data sampling, n = total data, and n0 = number of data with population value of 0 (zero).

The formula for calculating the Green Index (GI) (Ludwig & Reynold, 1998):

$$GI = \frac{(s^2/\bar{x})-1}{n-1} \quad [6]$$

GI = Green index, $\bar{x}$ = average data sampling, s2= variant, n = total data. Based on Ludwig and Reynold (1998), a range of values 0–1was used to read the Green index value, where the value of 0 indicated that the population is random and values close to 1 or 1 indicated that the population is grouped with increasingly strong. Based on this finding, the degree of population grouping (GI) of *H. bradyi* was in Table 1. to read it easier.

Table 1. Degrees of grouping according to the value of the Green Index (GI)

GI value	Category
0.00	Random
0.01– 0.20	Very weak
0.21 – 0.40	Weak
0.41 – 0.60	Medium
0.61 – 0.80	Strong
0.81 – 0.99	Very strong
1.00	Maximal

Source: Ludwig & Reynold (1998)

RESULTS AND DISCUSSION

H. bradyi is a sucking pest with a development stadia of egg, nymph, and adult (Figure 2). The *Helopeltis* eggs are difficult to be found. Female adults lay eggs in plant tissue. From a visual check, *Helopeltis* eggs are characterized by the white hair-strands (Figure 2A). *Helopeltis* adult has a dimorphism, i.e. black thorax in males (Figure 2C) and red/orange thorax in females (Figure 2D).

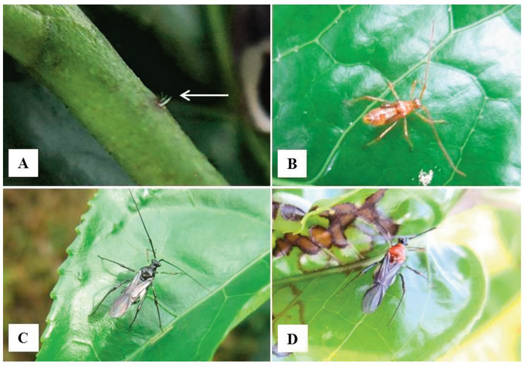

Figure 2. The stadia of *Helopeltis bradyi*: A. Egg, characterized with hair strands of egg on the internode of the tea shoot; B. nymph; C. Male adult (black thorax); and D. female adult (orange/red thorax) (Melina *et al.*, 2016)

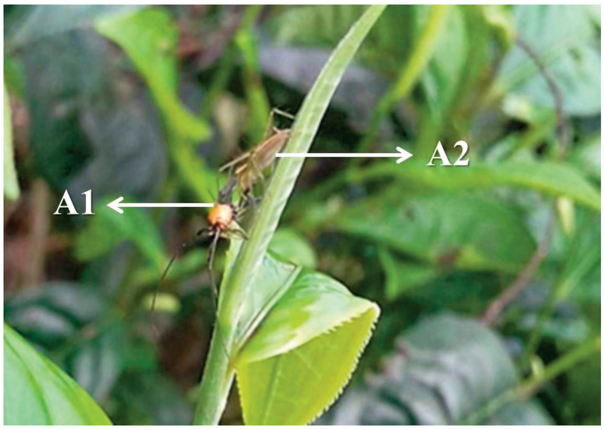

Figure 3. *Oxyopes javanus* preys on *Helopeltis bradyi*: *H. bradyi* (A1), *O. javanus* (A2)

Coexistence of Helopeltis bradyi *and* Oxyopes javanus

Field observations revealed that *O. javanus* preys on *H. Bradyi* (Figure 3). This finding showed that in PT Pagilaran tea plantations, *O. javanus* has a role as a predator of *H. bradyi*. The *H. bradyi* was found in the internode of 1st, 3rd, 4th, 5th, 5th, 6th, 7th, twig, and stem (Figure 4). The existence of pests without their natural enemy showed the displacement behavior of *H. bradyi*, which was moving towards the rootstock to hide when the disturbance was present (Roy *et al*., 2015). Meanwhile, the existence of *O. javanus* on the part of the tea plant was slightly found and only in the third part of the older leaves. This showed that *O. javanus* is a predator whose existence following the existence of their prey. The coexistence between *H. bradyi* and *O. javanus* in the tea plant was interpreted as the compatibility of the existence of each individual in the same part of the plant. Percentage of coexistence of pests and predators in various parts of tea plants in the morning, noon, and in the afternoon were 50.0%, 58.3%, and 66.7%, respectively (Tabel 2). The higher the value of coexistence, the greater the chance of predation between *O. javanus* and *H. bradyi*.

The ratio of predator-prey in the morning, noon, and afternoon were 1: 10.7; 1: 16,7, and 1: 10.0, respectively (Tabel 3). The predator-prey ratio showed the chances of *H. bradyi* as preys of *O. javanus*. The highest chance of predation occurred in the morning and afternoon, and similar with study reported by Basnet and Mukhopadhyay (2014) that *Helopeltis* actively eats in the morning and afternoon, thus *O. javanus* is more efficient as a predator of *H. bradyi*. In addition, *O. javanus* is general predators that can live from alternative prey, hence when the availability of prey is insufficient, *O. javanus* can grow and develop well by eating other insects (Symondson *et al*., 2002).

Vertical Distribution of Helopeltis bradyi *and* Oxyopes javanus

The distribution of *H. bradyi* and *O. javanus* in the tea plant was showed in Table 4 and Figure 4. The dispersion index (DI) showed the type of grouping based on the ratio of variant and mean. The DI of *H. bradyi* have a type of vertical grouping or aggregate distribution because it has a value of ID > 1. The *H. bradyi* grouping level based on the Green Index (GI) indicated a low grouping level. In general, insect populations in nature are clumped

Table 2. Percentage of existence and coexistence between *Oxyopes javanus* and *Helopeltis bradyi* in the morning, noon and afternoon

Time	Coexistence of *O. javanus* dan *H. bradyi*	Existence of *O. javanus*	Existence of *H. bradyi*
Morning	50.0	42.8	7.2
Noon	58.3	41.7	0
Afternoon	66.7	33.3	0

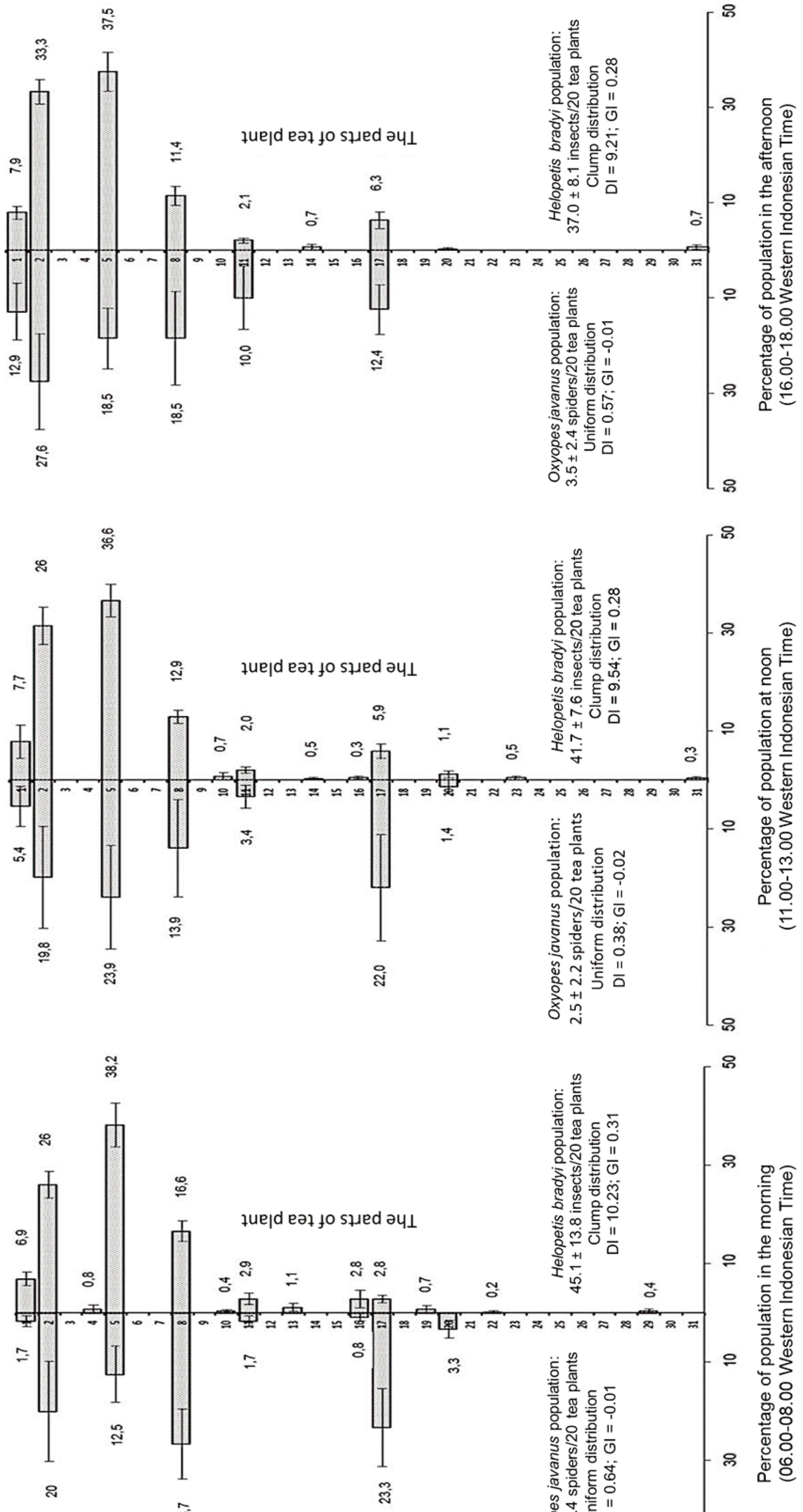

Figure 4. Vertical distribution of *Helopeltis bradyi* against their predators, *Oxyopes javanus*, in the tea plants in the morning, noon, and afternoon; the numbers of 1−31 are part of the tea plant

Table 3. The predator-prey population ratio between *Oxyopes javanus* and *Helopeltis bradyi*

Time	Mean (per 20 tea plants)		The ratio of Predator/Prey
	H. bradyi	*O. javanus*	
Morning	45.1	4.2	1:10.7
Noon	41.7	2.5	1:16.7
Afternoon	35.0	3.5	1:10

Table 4. Vertical distribution pattern of *Helopeltis bradyi* and *Oxyopes javanus* in the tea plantation

	Helopeltis bradyi			*Oxyopes javanus*		
	Morning	Noon	Afternoon	Morning	Noon	Afternoon
Mean ($\bar{x}$)	1.45	1.35	1.19	0.14	0.08	0.11
Variant (s^2)	14.89	12.83	10.99	0.09	0.03	0.06
Dispersion Index (DI)	10.23	9.54	9.21	0.64	0.38	0.57
Poisson (d Test)	17.09	16.24	15.83	-1.48*	-2.91*	-1.83*
Negative Binomial ($\hat{k}$)	0.31	0.27	0.16	-0.16*	-0.08*	-0.15*
Green Index (GI)	0.31	0.28	0.28	-0.01*	-0.02*	-0.01*
Distribution Pattern	Clump	Clump	Clump	Uniform	Uniform	Uniform
Description	Weak grouping	Weak grouping	Weak grouping	-	-	-

Description:

a. Mean ($\bar{x}$): insects or spiders per the parts of 20 tea plants

b. Dispersion Index (DI); If value = 1 showed random spatial distribution; value < 1 showed uniform distribution; and if value > 1 showed clumped distribution (Ludwig & Reynold, 1998).

c. Poisson test (random) with N ≥ 30 used value of d; If d > 1.96, Ho (random) was rejected, which did not follow the Poisson Distribution or not a random distribution

d. Negative binomial ($\hat{k}$) is a grouping parameter with a range of 0 - 2, the higher of the value of k^ until reaches an infinite number showed an approach to random distribution (Southwood, 1978)

e. Green Index (GI) showed the degree of grouping population (Tabel 3).

f. *The uniform distribution pattern was obtained if Ho was rejected in the Poisson Distribution and Negative Binomial resulting in negative values (Newman, 2013)

(Southwood, 1978; Ludwig & Reynold, 1998; Newman, 2013). The behavior of a grouping of insects could be interpreted that there are obstacles to the population of insect existence. Grouping behavior is that individuals group in parts preferred in their habitat, the existence of environmental plurality or reproductive models (Quinn & Dunham, 1983). Grouping of *H. bradyi* was vertically centered on a number of tea plants shoots, i.e. young leaf consisting of pekoe leaves, first young leaf, second young leaf, and third young leaf. This showed that the limitation of the population existence is caused by the feeding preference of *H. bradyi*. Study of the feeding preference of *H. theivora* Waterhouse, on the leaves and stems of tea (*Camellia sinensis* L. (O) Kuntze) showed that *H. theivora* adults preferred to eat the second leaf than the first and the third leaf (Bhuyan & Bhattacharya, 2006). Roy *et al* (2015) also explained that after hatching, nymphs immediately begin to eat young leaves and shoots.

The vertical distribution pattern of *O. javanus* was uniform because it has an DI < 1. The pattern of the uniform distribution is a pattern rarely found in organisms, hence the statistic analysis for that pattern is unavailable yet (Southwood, 1978; Ludwig & Reynold, 1998). Nature is a multifactorial system, where there are many interactions (biotic and abiotic) which can stimulate the existence of a pattern (Quinn & Dunham, 1983 *cit.* Southwood, 1978). In this study, the distribution pattern of *O. javanus* was concluded based on the rejection of the statistical test of *O. javanus* population in the Poisson test (random distribution), negative binomial test, and Green Index (clumped distribution) (Table 4). Newman (2013) reported that the conclusion of the distribution pattern for population data rejected in the Poisson and binomial negative tests are categorized into a uniform distribution. Furthermore, uniform distribution patterns are the result of negative interactions between individuals, such as competition in feeding preference or problems of separation (Quinn & Dunham, 1983 *cit.* Southwood, 1978), and this could occur to various types of organisms, including *O. javanus*.

In general, the grouping pattern of *H. bradyi* and *O. javanus* in the morning, noon, and afternoon has the same pattern (Figure 4). The part of the plant favored by *H. bradyi* is the young leaf consisting of pekoe leaves, first young leaf, second young leaf, and third young leaf. Whereas the existence of *O. javanus* tends to follow the existing pattern of *H. bradyi*. *O. javanus* spiders are mostly found in the canopy (top layer) of tea, the same habitat as *H. brady* (Basnet & Mukhopadhyay, 2014).

Based on this study, mechanical control and the use of *Helopeltis* natural enemies, such as *O. javanus*, could be an alternative control technique. Mechanical control can be related to the process of plucking the tea leaves and trimming tea plants. Plucking cycles could be arranged with the longevity of *Helopeltis* stadia which distributed vertically. Therefore, when the plucking young leaves, the control process will conduct at the same time by the workers. Furthermore, the population of *O. javanus* as predator of *H. bradyi* could be increased.

CONCLUSION

This study showed that *H. bradyi* grouping was vertically centered on the young leaves consisting of pekoe leaves, first young leaf, second young leaf, and third young leaf. There was a trend that the existence of *O. javanus* followed the existence of *H. bradyi*. Coexistence between *H. bradyi* and *O. javanus* in the same part of the plant, occurred in the morning of 50.0%, at noon of 58.3%, and in the afternoon of 66.7%. The parts of the plant for the coexistence are in pekoe leaves; 1st, 2nd, 3rd, and 4th of young leaves; and 1^{s}t of older leaves. Therefore, when the prediction of *H. bradyi* attack was high, scissor system and plucking it once out without leaving shoots in the field was recommended as control techniques. Furthermore, besides reducing the pest population on the shoots, also reducing the food availability for the eggs hatched after the plucking. *O. javanus* population in the field could be increased by a mass rearing (augmentation) to maximize the potential for predation on *H. bradyi*.

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