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Population Structure of *Thrips parvispinus* Karny (Thysanoptera: Thripidae) and Population Abundance of Predatory Insect on Red Chili (*Capsicum annuum* L.) Treated with Imidacloprid Insecticide

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ABSTRACT

In Indonesia, the pest *Thrips parvispinus* Karny is a major problem for red chili plants. Most pest control techniques rely on synthetic pesticides, resulting in environmental degradation, the extinction of natural enemies, and the emergence and resilience of a variety of different pests. The aim of this study is to determine the impact of a 25% Imidacloprid insecticide on population density and the proportion of infestations and natural enemies in the field. A randomized block design with 5 treatments and 5 replications was utilized in this field investigation. Plant samples were collected in a "U-shaped" pattern. According to the findings, a 25% Imidacloprid pesticide had a significant influence on population density and *T. parvispinus* attack on red chili plants. Moderate damage was caused by *T. parvispinus'* infestation on red chili plants using 50-200 $L.ha^{-1}$ 25 % Imidacloprid pesticide. Furthermore, a 25 % Imidacloprid insecticide applied at a rate of 100 $L.ha^{-1}$ had a significant influence on the population variety and abundance of *T. parvispinus* natural enemies. A 25 % Imidacloprid insecticide dosage increase was shown to have a very strong relationship with a reduction in population density, the proportion of *T. parvispinus* assault, and the variety and quantity of natural enemies in red chili. Thus, a 25 % Imidacloprid insecticide at a rate of 100 $L.ha^{-1}$ proved successful in reducing *T. parvispinus* while remaining safe for natural enemies. Future pest control techniques must still be based on improved field data collection, such as data on pesticide contamination or other anthropogenic chemicals, which may also be used to estimate natural enemy population levels in the field.

INTRODUCTION

Red chili *(Capsicum annuum* L.*)* is one of the top national commodities generating public income and state foreign exchange in the non-oil and gas sector. Compared to its potential production of more than 20 $tons.ha^{-1}$, the average red chili yield per farmer in 2015 was 8.65 $tons.ha^{-1}$ (BPS 2015). The infestation of *Thrips parvispinus* Karny in every growing season causes low red chili yield (Johari et al. 2016). These pests target red chili shoots, young leaves, and flowers by inserting their stylets into the epidermal tissue, palisade tissue, and mesophyll cells to extract nutrients from the plant fluid (Merta et al. 2017). The brown-turned silvery spots are typical symptoms of a normal infestation on the foliage. Damage to the leaves can interfere with the photosynthesis process, resulting in a reduction in leaf photosynthesis rate (Gassmann 2004). Curling leaves and stunted terminal shoots are two more indications of this pest infestation (Tyagi et al. 2015).

Classical biological management utilizing imported exotic natural enemies has a long history of effectiveness in controlling target pest populations in many nations (Horrocks et al. 2020). Natural enemies from predatory groups may be employed to naturally control these pests (van Lenteren 2012, Duan et al. 2015, Barratt et al. 2018, Supartha et al. 2020). Natural enemies, for example, are reported to have had a significant part in at least a 50% decrease in pest infestation on certain agricultural fields, which contribute US$13 billion in ecosystem benefits in the United States each year (Losey & Vaughan 2006).

However, if biological control measures fail to manage certain pests, further management methods, such as synthetic pesticides are required. In 2003-2005, Prabaningrum & Moekasan, (2008) reported the control activities on red chili planting in the West Bandung Regency, Indonesia with agrochemicals such as Imidacloprid insecticide. In Indonesia, rice farmers have been using imidacloprid pesticides since 1994 (Thorburn 2015). This pesticide is good and efficient against pests such as whitefly and aphids (Hartwig et al. 1991). According to Firmansyah et al. (2014), of five imidacloprid insecticide doses namely 3,200 $g.ha^{-1}$, 1,600 $g.ha^{-1}$, 800 $g.ha^{-1}$, 400 $g.ha^{-1}$, and 200 $g.ha^{-1}$, the suggested amount for controlling brown leafhoppers was 800 $g.ha^{-1}$. In another case, the imidacloprid pesticide was well-known for its effectiveness in suppressing the Silverleaf whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) (Setiawati et al. 2007). In addition to the pesticide Imidachloride, there is another insecticide with the active ingredient Fipronil 50 $g.L^{-1}$ that considerably lowers the dominance and diversity index of the yellow rice stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Pyralidae) and their abundance of parasitoids, especially at higher doses (Putra et al. 2017).

This field study aimed to assess the efficiency of 25% Imidacloprid insecticide in suppressing the population of thrips, as well as its effect on the population diversity and abundance of *T. parvispinus* on red chili *(Capsicum annuum L.).* In terms of the use of synthetic pesticides that impact the balance of insects in agricultural landscapes, these results may be useful information, particularly for farmers and relevant authorities. Additionally, environmental and human health must be emphasized via the application of Integrated Pest Management.

MATERIALS AND METHODS

Study Area

This study was carried out in Kerta Village, Payangan District, Gianyar Regency, Bali Province, on a *T. parvispinus*-attacked red chili (Pilar variety) plantation owned by local farmers. The study site is located 850 meters above sea level with temperatures ranging from 26 to 28℃ and 77% humidity. Meanwhile, the laboratory-scale study was carried out at IPM Lab, Faculty of Agriculture, Udayana University, Denpasar-Bali.

Research Design

This study used Randomized Block Design with five treatment doses of 25% Imidacloprid insecticide: 50 g/ha, 100 $g.ha^{-1}$, 150 $g.ha^{-1}$, and 200 $g.ha^{-1}$, and the control (no insecticide) in five replications. The total land area is 1,440 m^2 with a bed area of 36 m^2. The plant population per bed was 144 plants, with a spacing of 50 cm × 45 cm. The number of plants sampled per bed was ten with a "U" (U-shape) sampling technique. When the red chili plants were 4 weeks old after planting (wap) or 10 *T. parvispinus* nymphs were identified per plant, the 25% Imidacloprid pesticide was applied once a week for a total of ten applications using a high-pressure sprayer.

Population Density

The population density of *T. parvispinus* was observed on three selected red chili blooms. *T. parvispinus* population density (PD) is determined using the following formula:

$$Population\ density = \frac{number\ of\ individuals}{area\ (m^2)}$$

Percentage of Attack

The percentage of attack was determined using six leaves namely every two leaves from the bottom, middle, and top of the red chili plant. The percentage of attack (P) is calculated using the formula:

$$P = \frac{number\ of\ affected\ leaves\ (a)}{total\ number\ of\ leaves\ observed\ (b)}$$

Diversity of Natural Enemies

Shannon-Weaver's natural enemy diversity formula (Price, 1984) :

$$H' = \sum Pi\ logPi = \sum (\frac{ni}{N} log \frac{ni}{N})$$

Where:

H' = Diversity Index

Pi = *ni/N* (the number of i-species individuals divided by the total number of individuals).

ni = Number of i-species individuals

N = Total number of individuals

The observation was performed by collecting specimens, documenting, and photographing the type and quantity of predators encountered in the field once a week for identification in the laboratory.

Data Analysis

ANOVA (SPSS 23.0, IBM, USA) was used to evaluate data on population density and the proportion of *T. parvispinus* assaults on plants, as well as the index of population diversity and predator abundance on red chili. If the treatment has a significant effect on the observed variables, the Least Significant Difference (LSD) test at a 5% level ($P<0.05$) will be conducted. Meanwhile, regression analysis was performed to investigate the relationship between demographic data and the proportion of infestations (MS Excel 2019, Microsoft Windows USA).

RESULTS AND DISCUSSION

Population Density

Based on the results, *T. parvispinus* population density decreased from 7 weeks after planting (wap) to 13 wap. This happened as a result of 25% Imidacloprid insecticide application in lowering *T. parvispinus* population density on red chili plants (Table 1). This is supported by Abdel Farag El-Shafie (2020) that pest population density may be reduced by application-based control methods. The 25% Imidacloprid has a high effectiveness value for eliminating insects including aphids, peach aphids, armyworms, rice ear bugs, and brown leafhoppers, and is generally safe because of its minimal toxicity to mammals (Saharan et al. 2014). In addition to affecting the density of insect populations, exposure to imidacloprid for 35 days affects the physiology of crops and is easily concentrated on the shoots of vegetables which are generally used as a source of nutrition by several invasive pests in the field (Li et al. 2019).

The results are supported by Supartha et al. (2002) that pesticides with systemic and contact characteristics can impair the growth and development of insect larvae. The decrease in population density of *T. parvispinus* at the 10 to 13 Week after Planting (WAP) was assumed to be related to the physical traits (the developed plant tissue, a decrease in the food supply, and the appearance of red chili plants. Histological, physiological, and behavioral effects of exposure to low doses of the insecticide Imidacloprid were also investigated in *Drosophila melanogaster* and these findings indicate that oxidative stress is a key factor in the process of action of this insecticide by generating Ca2+ fluxes that enter neurons and increase levels of relative oxygen species (ROS) in fly larvae brain (Martelli et al. 2020).

Table 1: The effect of 25% imidacloprid insecticide on population density of *T. parvispinus* in red chili plants.

Treatment Dose (g.ha^{-1})	Population density of *T. parvispinus* [m^2]									
	Week after planting (WAP)									
	4	5	6	7	8	9	10	11	12	13
200	14.9 a	14.6 a	13.1 a	11.8 a	11.7 a	11.3 a	10.2 a	8.4 a	6.6 a	4.3 a
150	15.0 a	14.6 a	14.1 a	12.2 ab	11.9 a	11.7 a	10.7 a	8.9 a	7.2 a	4.6 a
100	15.3 a	14.8 a	14.3 a	12.9 ab	12.4 ab	13.0 ab	12.1 b	9.7 ab	7.9 a	5.3 a
50	15.4 a	15.5 a	15.8 b	13.5 b	13.1 b	14.0 b	13.4 b	11.2 b	10.0 b	6.7 b
0	15.5 a	16.1a	16.1 b	17.2 c	19.1 c	23.1 c	20.0 c	17.3 c	13.0 c	8.6 c

Note: the numbers followed by the same letter in the same column show no significant difference in the *Least Significant Different* (LSD) Test at the 5% level *(<0.05)*.

Table 2: The effect of 25% imidacloprid insecticide on percentage of attack index in red chili plants.

Treatment Dose (g/ha)	Week after planting (WAP)									
	4	5	6	7	8	9	10	11	12	13
200	15.7 a	16.0 a	15.7 a	12.9 a	11.0 a	10.3 a	9.3 a	6.5 a	6.2 a	4.4 a
150	15.9 a	16.2 a	16.4 a	14.1 ab	11.9 a	11.7 a	9.9 a	7.4 a	6.2 a	4.5 a
100	16.3 a	16.2 a	16.8 ab	15.0 b	14.1 b	14.5 b	11.6 b	10.0 b	7.4 ab	4.8 a
50	17.1 a	17.4 a	17.6 ab	15.8 b	14.7 b	15.6 b	12.8 b	11.6 b	8.1 b	5.3 a
0	17.5 a	17.6 a	19.1 b	21.0 c	21.9 c	25.9 c	22.5 c	17.3 c	12.9 c	8.7 b

Note: the numbers followed by the same letter in the same column show no significant difference in the *Least Significant Different* (LSD) Test at the 5% level *(<0.05)*.

Percentage of Attack Index

Based on the results of data analysis, the effect of 25% Imidacloprid insecticide on the percentage of attack was substantially different between the control and the treatment studied. From top to lowest, the percentage of attacks was 50 g.ha^{-1}, 100 g.ha^{-1}, 150 g.ha^{-1}, and 200 g.ha^{-1} (Table 2). The 25% Imidacloprid insecticide, used as a contact and systemic poison against *T. parvispinus*, has the potential to block the signal flow that would otherwise travel to the receiving neuron, making it impossible for the nerve to receive messages spontaneously. As a result, insects suffer paralysis leading to death (Wang et al. 2008, Khoa et al. 2018).

Diversity of Natural Enemies Index

Based on the results, 25% Imidacloprid insecticide to the diversity of natural enemies at 50 g.ha^{-1} to 150 g.ha^{-1} doses were not significantly different from the control treatment. These results indicated that the insecticide had no significant effect on natural enemies, especially predatory insects. This can be seen in 50 g.ha^{-1} and 150 g.ha^{-1} doses that several types of predatory insects were still able to survive. However, not all types of natural enemies can survive at high doses, for example, at 200 g.ha^{-1} doses, the predatory insects significantly decreased compared to the control. This is presumably because several types of predatory insects exposed to the 25% Imidacloprid insecticide were unable to maintain the viability of the toxic nature at the highest concentration (Table 3). The 25% Imidacloprid insecticide can penetrate the bodies of insects by systemic and contact poisoning (Kreutzweiser et al. 2008).

The Abundance of Natural Enemies

Based on the results, 25% Imidacloprid insecticide had a significant effect compared to the control, especially at 100 g.ha^{-1}, 150 g.ha^{-1}, and 200 g.ha^{-1} (Table 4). The unwise use of synthetic insecticides (especially non-selective ones) can reduce the population of insect pests and can adversely affect the decrease in the abundance of natural enemy populations in fields (El-Wakeil et al. 2013, Göldel et al. 2020, Gesraha & Ebeid 2021).

Relationship Between 25% Imidacloprid Insecticide Dose and Population Density and Percentage of Attack

The R^2 value of population density and percentage of attack was 0.6708 and 0.9137, respectively (Fig. 1). These results indicated a positive and very strong relationship between the 25% Imidacloprid Insecticide and population density as well

Table 3: The effect of 25% imidacloprid insecticide on diversity of natural enemies index in red chili plants.

Treatment Dose (g.ha^{-1})	Week after planting (WAP)									
	4	5	6	7	8	9	10	11	12	13
200	0.60 a	0.59 a	0.59 a	0.56 a	0.56 a	0.56 a	0.55 a	0.52 a	0.51 a	0.48 a
150	0.56 a	0.61 a	0.62 ab	0.64 ab	0.64 ab	0.64 ab	0.62 ab	0.60 ab	0.60 ab	0.58 a
100	0.57 a	0.61 a	0.63 ab	0.64 ab	0.66 b	0.67 b	0.65 ab	0.64 b	0.63 ab	0.60 a
50	0.60 a	0.65 a	0.65 ab	0.69 ab	0.70 b	0.68 b	0.68 b	0.70 b	0.65 b	0.61 a
0	0.59 a	0.66 a	0.69 b	0.73 b	0.73 b	0.74 b	0.72 b	0.71 b	0.64 b	0.61 a

Note: the numbers followed by the same letter in the same column show no significant difference in the Least Significant Different (LSD) Test at the 5% level *(<0.05).*

Table 4: The effect of 25% imidacloprid insecticide on abundance index of natural enemies in red chili plants.

Treatment Dose (g.ha^{-1})	Week after planting (WAP)									
	4	5	6	7	8	9	10	11	12	13
200	11,1 a	11,6 a	10,8 a	10,1 a	10,1 a	9,5 a	9,6 a	8,5 a	8,7 a	8,2 a
150	10,8 a	11,3 a	11,5 a	12,1 a	11,8 a	12,2 b	11,6 b	10,9 b	9,7 a	9,0 ab
100	10,8 a	11,4 a	12,1 ab	12,4 a	12,3 a	12,2 b	12,2 b	11,7 b	10,3ab	9,0 ab
50	12,3 a	12,9 a	13,8 ab	15,0 b	15,0 b	16,3 c	14,8 c	13,9 c	11,9bc	10,7 bc
0	11,9 a	13,3 a	15,0 b	15,4 b	16,1 b	16,9 c	16,3 c	15,4 c	12,4 c	11,2 c

Note: the numbers followed by the same letter in the same column show no significant difference in the Least Significant Different (LSD) Test at the 5% level *(<0.05).*

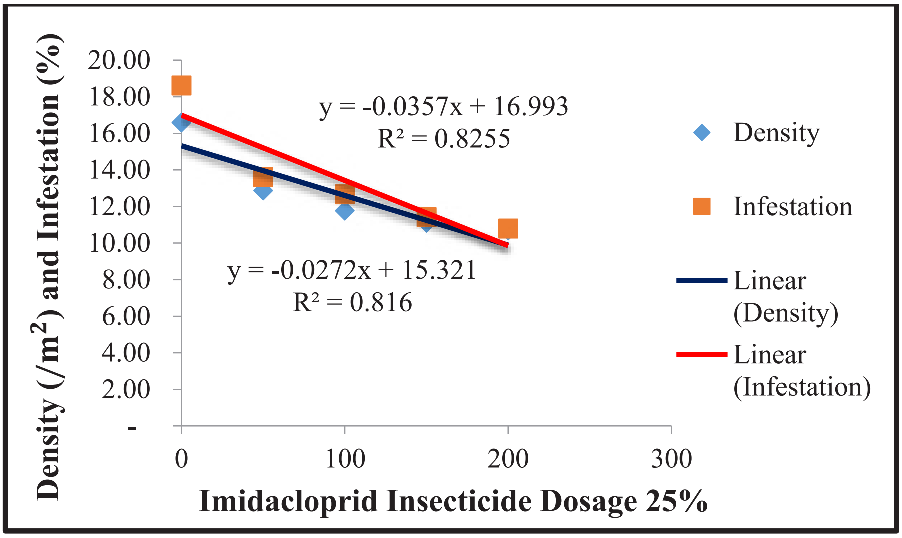

Fig. 1: Relationship between 25 % Imidacloprid insecticide dose with population density and percentage of attack.

as attack percentage. Thus, 25% Imidacloprid Insecticide was very effective in suppressing population density and the percentage of *T. parvispinus* attack on red chili plants.

The decrease in population density and the percentage of attacks was in line with the increase in the tested dose, meaning that the higher the dose applied, the lower the population density and the percentage of attacks. The population decrease was caused by the direct effect of the 25% Imidacloprid insecticide either by contact or systemically on the body of the insect (Sanchez-Bayo et al. 2013, Pisa et al. 2021). The 25% Imidacloprid insecticide had a strong influence on the types of insect pests in eating, grating, and sucking (Ahmed et al. 2014). The way the insecticide works is very compatible with the behavior of *T. parvispinus* attacking leaves and flowers, namely by grinding and sucking the liquid from the leaves and flowers of red chili plants containing 25% Imidacloprid insecticide. This is supported by Summers et al. (2004) that the 25% Imidacloprid insecticide is effective in suppressing population density and the attack of aphids on red chili plants.

Relationship Between 25% Imidacloprid Insecticide dose and the Diversity and Abundance of Natural Enemies

The R^2 value of diversity and abundance of natural enemies

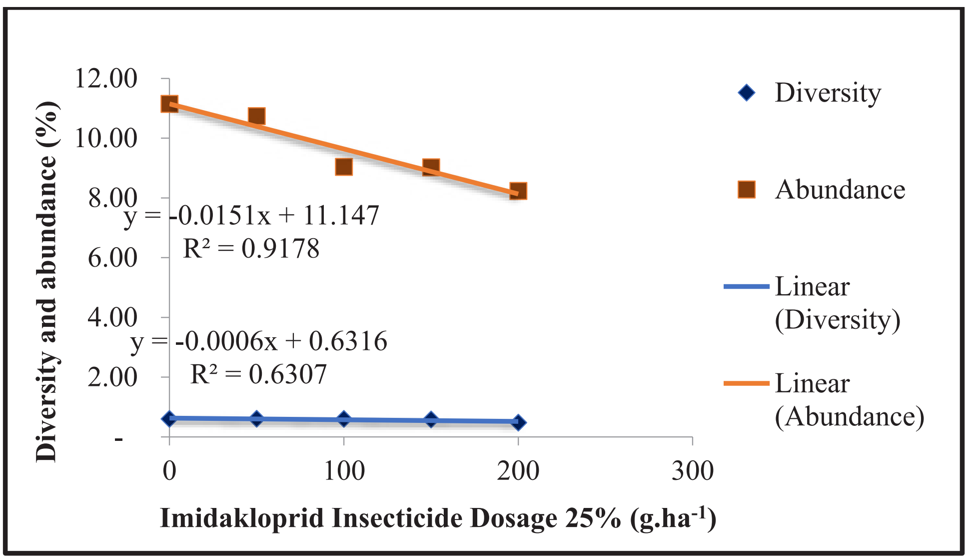

Fig. 2: The relationship between 25% Imidacloprid insecticide and the diversity and abundance of *T. parvispinus* natural enemies.

was 0.6307 and 0.9178, respectively (Fig. 2). These results indicated a positive and very strong relationship between the 25% Imidacloprid Insecticide and the diversity and abundance of natural enemies. An increase in the dose of 25% Imidacloprid insecticide significantly decreased the abundance of natural enemies in red chili plantations. The use of selective insecticides even at high doses can have a negative effect on decreasing the abundance of natural enemies (Xiao et al. 2016). Insecticides cause species shift phenomena, trophic level simplification, and pest resurgence (Yamamuro et al. 2019). The overall density of predators applied with insecticides was lower than in the control plots (Janssen & Rijn 2021).

CONCLUSION

The 25% Imidacloprid insecticide had a significant effect on population density and the attack of *T. parvispinus* on red chili plants. The percentage of *T. parvispinus* attack on red chili plants with the 25% Imidacloprid insecticide at a dose (50-200 $L.ha^{-1}$) was included in the "mild damage" category. 25% Imidacloprid insecticide had a significant effect on the diversity and abundance of natural enemies at a dose of 100 $g.ha^{-1}$. An increase in the dose of 25% Imidacloprid insecticide showed a very strong relationship to the decrease in population density, the percentage of *T. parvispinus* attack, and the diversity and abundance of natural enemies in red chili *(Capsicum annuum* L.*)*. Thus, 100 $L.ha^{-1}$ 25% Imidacloprid insecticide was effective in controlling *T. parvispinus* and safe for natural enemies.

It is still necessary to conduct further research on the contamination of 25% Imidacloprid insecticide on heavy metals in horticultural crops and their impact on human health, to provide important information on human health and the agricultural environment.

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