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Mortality of *Plutella xylostella* Linn. from Cabbage Crops in Kakaskasen II Village, Tomohon City, and Its Resistance to Several Commercial Insecticides

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ABSTRACT

The main issue in improving the productivity of cabbage crops in Tomohon City is pest infestation, one of which is the pest *Plutella xylostella* L. This study aims to determine the mortality response and resistance of *P. xylostella* larvae to several types of commercial insecticides in the laboratory. Three commercial insecticides commonly used by farmers, namely deltamethrin, emamectin benzoate, and profenofos, were tested on 3rd instar *P. xylostella* larvae using the leaf-dip method, with the test larvae being starved beforehand. Insect mortality was observed at 96 hours after treatment (HAT) for the F1 generation (field population) and the F5 generation (laboratory population). Data were analyzed using analysis of variance (ANOVA) in a Completely Randomized Design. The resistance of *P. xylostella* to commercial insecticides was calculated using the Resistance Ratio (RR), obtained by comparing the LC50 of the F1 generation population with the LC50 of the F5 generation population. The results of the toxicity test on the dose treatments for each insecticide showed a significant effect on the mortality of the test larvae. The mortality of F1 generation *P. xylostella* larvae treated with varying doses of deltamethrin, emamectin benzoate, and profenofos showed low mortality at doses of 1.5 ml/l, 2.0 ml/l, and 2.5 ml/l, respectively: deltamethrin 16.67%, 33.33%, 36.67%; emamectin benzoate 16.67%, 30.00%, 46.67%; and profenofos 13.33%, 26.67%, 46.67%. In contrast, the mortality of F5 generation (laboratory population) *P. xylostella* larvae at doses of 1.5 ml/l, 2.0 ml/l, and 2.5 ml/l was higher, respectively: deltamethrin 73.33%, 93.33%, 96.33%; emamectin benzoate 76.67%, 93.33%, 100.00%; and profenofos 76.67%, 90.00%, 100.00%. *P. xylostella* controlled using deltamethrin showed a resistance level of 2.15 times, emamectin benzoate 2.17 times, and profenofos 2.06 times.
Keywords: *P. xylostella*; deltamethrin; emamectin benzoate; profenofos

INTRODUCTION

Cabbage is a highly sought-after horticultural crop with considerable economic value. It provides essential nutrients, including vitamins, minerals, carbohydrates, proteins, and fats. Cabbage is also a key leafy vegetable in mountainous regions. In addition, it is known to be rich in vitamin A, vitamin C, vitamin B, niacin, and minerals like calcium, phosphorus, iron, and sulfur (Kim *et al*., 2014).

The cabbage leaf caterpillar, *Plutella xylostella* Linn. (Lepidoptera: Yponomeutidae), is a major pest that causes significant damage to plants in the Brassicaceae family, particularly cabbage (Furlong *et al*., 2013). In the dry season, this pest can drastically reduce cabbage yields, even leading to complete crop failure (Zalucki *et al*., 2012). In Tomohon, reports indicate that damage to cabbage crops from *P. xylostella* attacks reached 38%, with losses escalating to 100% during the dry season (Hosang and Sembel, 1983). The Integrated Pest Management (IPM) approach for cabbage crops has been established for many years; however, numerous farmers continue to depend on synthetic insecticides to manage *P. xylostella* (Rauf *et al*., 2005). The prolonged use of synthetic insecticides can result in several negative consequences, one of which is the development of resistance in pests. Global reports have documented *P. xylostella* resistance to pyrethroid and organophosphate insecticides. In regions such as Australia, China, India, Nicaragua, Pakistan, the Philippines, South Africa, and South Korea, this resistance has become a major challenge in pest management (Furlong *et al*., 2013). Research by Zalucki *et al*. (2012) revealed that *P. xylostella* has developed resistance to over 90 insecticide types, including pyrethroids, organophosphates, and carbamates. This underscores the need for more sustainable pest control strategies, such as the use of biopesticide-based insecticides, insecticide rotation, and the integration of biological control methods (Sarfraz *et al*., 2020).

Recent research indicates that insecticide resistance has been observed in more than 600 insect species globally, including key agricultural pests like *P. xylostella*, *Helicoverpa armigera*, and *Bemisia tabaci* (Sparks & Nauen, 2015). In Indonesia, resistance to insecticides has been found in several significant pests, including *P. xylostella*, which has developed resistance to pyrethroids and organophosphates (Furlong *et al*., 2013). This underscores the importance of adopting a more comprehensive approach to resistance management, incorporating biopesticide-based insecticides, rotating insecticides with different modes of action, and integrating biological control methods (Sarfraz *et al*., 2020).

The rise in insecticide resistance across various insect species in recent years has become the most critical challenge since the widespread adoption of synthetic organic insecticides globally after World War II. While resistance to inorganic insecticides has been recognized since the 1910s, the problem has significantly worsened following the introduction of synthetic organic insecticides (Sparks & Nauen, 2015). Insecticide resistance is a worldwide issue affecting both developed and developing nations, including Indonesia (Furlong *et al*., 2013). The primary cause of the increase in resistance is the improper application of insecticides by humans, often without a full understanding of the basic properties of chemical insecticides, including how resistant populations can develop (Bass *et al*., 2015). Misuse of insecticides, such as incorrect dosing, excessive frequency of application, and failure to rotate insecticides, has further accelerated the development of resistant insect populations (Sarfraz *et al*., 2020). Additionally, a lack of understanding about the mechanisms of resistance and insect population dynamics has also contributed to this growing problem (Tabashnik *et al*., 2013).

At present, there is limited research on the resistance of *P. xylostella* to the various commercial insecticides used by farmers, especially on cabbage crops in Kakaskasen II Village, Tomohon City. Nevertheless, insecticide resistance remains a critical issue that could jeopardize agricultural productivity and the long-term effectiveness of pest control. Consequently, this study is necessary to gather data on the resistance levels of *P. xylostella* to the insecticides employed by farmers. The findings are anticipated to provide valuable insights for stakeholders in developing more effective and sustainable pest management strategies. Furthermore, the results may serve as a basis for creating a more integrated resistance management approach, including insecticide rotation, the use of biopesticide-based insecticides, and the incorporation of biological control methods. This approach aims to reduce farmers' reliance on synthetic insecticides, thus minimizing the negative effects on both the environment and human health.

METHODS

Larvae and pupae of *Plutella xylostella* were collected from cabbage farms in Kakaskasen II Village, North Tomohon District, Tomohon City. The toxicity and resistance tests for *P. xylostella* were conducted at the Plant Pests and Diseases Laboratory, Faculty of Agriculture, Sam Ratulangi University. The materials and equipment used in the study included *P. xylostella*, cabbage plants, distilled water, deltamethrin insecticide (Decis 25, EC), emamectin benzoate (Proclaim 5 SG), propenofos (Curacron 500 EC), adhesive (Agristik), polybags, cabbage seeds, propagation cages, hand counters, insect nets, collection bottles, pipettes, petri dishes, cutters, CD Room, brushes, loupes, sample boxes, digital scales, and cameras.

Cabbage plants were grown in polybags without pesticide application. Leaves from 1-2-month-old cabbage plants were used to propagate *P. xylostella* larvae. The larvae used in the tests were F1 generation third instar larvae (field population) and F5 generation larvae (laboratory population). The research involved toxicity and resistance tests. Insecticide toxicity was tested using the leaf dip method. The commercial insecticides tested included deltamethrin, emamectin benzoate, and profenofos, each at specific concentrations: deltamethrin at 0.0 ml/l, 1.5 ml/l, 2 ml/l, and 2.5 ml/l; emamectin benzoate at 0.0 gr/l, 0.05 gr/l, 0.15 gr/l, and 0.25 gr/l; and profenofos at 0.0 ml/l, 1.0 ml/l, 1.5 ml/l, and 2.0 ml/l. Each experiment was repeated three times, with each replicate using 10 third instar larvae. The diluent used was distilled water containing 0.2 ml/L Agristick adhesive (b.a. alkylaryl polyglycol ether 400 g/L).

For each test, cabbage leaves were cut into 4 cm x 4 cm pieces and dipped individually in the insecticide solution. One leaf piece was placed in a test container covered with tissue, and 10 third instar larvae were added. Three replicates were used per concentration. The larvae were allowed to feed on the treated leaves for 48 hours and then replaced with untreated leaves until the fourth day. The number of dead larvae was recorded at 96 hours after treatment (JSP), followed by an analysis of variance on the mortality of the test larvae.

Resistance was determined using four concentration levels with three replicates, including a control. The resistance ratio (NR) was calculated as follows:

$$NR = \frac{LC50\ field\ insects}{LC50\ laboratory\ insects}$$

Resistance is indicated when NR > 1 (Winteringham, 1969). Cumulative mortality data at 96 JSP were analyzed using probit analysis with SPSS Ver. 21 software.

RESULTS AND DISCUSSION

Toxicity Testing

The variance analysis indicated that the insecticide dosage significantly influenced the mortality rate of *P. xylostella* larvae from both the F1 generation (field population) and the F5 generation (laboratory population) when exposed to three insecticides: deltamethrin, emamectin benzoate, and profenofos. The average mortality rates of *P. xylostella* larvae from the F1 and F5 generations for each insecticide—deltamethrin, emamectin benzoate, and profenofos—are presented in **Table 1**.

Table 1. Average mortality of *P. xylostella* larvae from the F1 and F5 generations using three types of insecticides.

Treatments	Average Mortality of *P. xylostella* Larvae (%)					
	DF1	DF5	EF1	EF5	PF1	PF5
Control	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
B (1.5 ml/l)	16.67b	73.33b	16.67b	76.67b	13.33b	76.67b
C (2.0 ml/l)	33.33c	93.33c	30.00c	93.33c	26.67c	90.00c
D (2.5 ml/l)	36.67c	96.33c	46.67d	100.00c	46.67d	100.00c

Description:
DF1= Deltamethrin Insecticide in F1 Generation of *P. xylostella*
DF5= Deltamethrin Insecticide in the F5 Generation of *P. xylostella*
EF1= Emamectin Benzoate Insecticide F1 Generation *P. xylostella*
EF5= Emamectin Benzoate Insecticide F5 Generation *P. xylostella*
PF1= Profenofos Insecticide F1 Generation *P. xylostella*
PF5= Profenofos Benzoate Insecticide F5 Generation *P. xylostella*

Table 1 reveals that *P. xylostella* larvae from the F1 generation, when exposed to different doses of deltamethrin, emamectin benzoate, and profenofos insecticides, displayed low mortality at doses of 1.5 ml/l, 2.0 ml/l, and 2.5 ml/l, with the following results: deltamethrin 16.67%, 33.33%, 36.67%; emamectin benzoate 16.67%, 30.00%, 46.67%; and profenofos 13.33%, 26.67%, 46.67%. On the other hand, *P. xylostella* larvae from the F5 generation exhibited significantly higher mortality rates at the same doses: deltamethrin 73.33%, 93.33%, 96.33%; emamectin benzoate 76.67%, 93.33%, 100.00%; and profenofos 76.67%, 90.00%, 100.00%. This marked difference in mortality rates between the F1 and F5 generations indicates that the larvae from the F1 generation had relatively lower mortality compared to the F5 generation, which showed higher average mortality. The F1 generation comes from the field, where the larvae have been frequently exposed to insecticides, which may have led to a higher resistance to insecticide treatments. In contrast, the F5 generation, which has been kept in a laboratory environment for an extended period, has developed a greater sensitivity to insecticides due to changes in resistance. Shehzad *et al*. (2023) report that arthropods utilize various behavioral and biochemical mechanisms to overcome harmful chemicals, which contribute to the evolution of resistance. Thus, the F1 population of *P. xylostella* is more likely to exhibit resistance to insecticide exposure because of the adaptive mechanisms it has developed over time. The F1 generation, obtained from the field, shows clear signs of resistance to all three insecticides, as reflected by the lower average mortality rate compared to the higher mortality rate observed in the F5 generation.

Resistance Testing

The resistance test was carried out by calculating the Resistance Ratio (RR) for each insecticide applied. The RR is calculated by comparing the LC50 values of the field population with those of the laboratory population. The field population corresponds to the F1 generation, while the laboratory population refers to the F5 generation. The LC50 values and the Resistance Ratios (RR) for each insecticide against the *P. xylostella* population from Kakaskasen II, both F1 and F5 generations, are shown in Table 2. The Resistance Ratios are derived by comparing the LC50 values of the F1 generation with those of the F5 generation.

Table 2. LC50 values and Resistance Ratios for each insecticide against the *P. xylostella* population from F1 and F5 generations.

Insecticide Type	LC50		NR
	F1	F5	
Deltamethrin	2.504	1.163	2.15
Emamectin Benzoate	2.651	1.219	2.17
Profenofos	2.603	1.262	2.06

Table 2 shows that the Resistance Ratios (RR) for the insecticides deltamethrin, emamectin benzoate, and profenofos are 2.15, 2.17, and 2.06, respectively. This indicates that P. xylostella exposed to deltamethrin has developed 2.15 times more resistance, 2.17 times with emamectin benzoate, and 2.06 times with profenofos. Resistance in *P. xylostella* to these insecticides has been previously reported by various studies in cabbage crops in Central Java and South Sulawesi, with NR values that even surpassed those observed in this research (Moekasan *et al*., 2004 and Agboyi *et al*., 2016).

Insects with shorter life cycles, which enable them to produce many generations in a year, tend to develop resistance to insecticides faster than those with longer life cycles that produce only one generation annually (Tabashnik *et al*., 2013). This is because insects with rapid life cycles generate more generations, allowing genetic mutations that lead to resistance to accumulate more quickly (Bass *et al*., 2015). For instance, *P. xylostella* (cabbage worm), capable of producing 15-20 generations per year, has developed resistance to various insecticides in a relatively short time (Furlong *et al*., 2013). When it comes to genetic complexity, the greater the number of genes involved in regulating an insect's resistance, the slower resistance tends to evolve. In contrast, if there are fewer resistance-regulating genes, insects can become resistant to insecticides at a faster rate (Sparks & Nauen, 2015). For example, resistance to pyrethroid insecticides in *P. xylostella* is often driven by one or a few key genes, such as mutations in the kdr gene (knockdown resistance), resulting in the quick development of resistance (*Sarfraz et al*., 2020). In contrast, resistance that involves multiple genes, such as in cases with insecticides that have complex modes of action, takes longer to develop (Tabashnik *et al*., 2013).

Given the resistance situation of *P. xylostella* in the Kakaskasen II population, Tomohon City, it is crucial to adopt effective strategies and management practices for insecticide use to prevent further resistance development in the field. Until now, resistance management has primarily involved rotating insecticides based on different active ingredients. However, the Insecticide Resistance Action Committee (IRAC) stresses that rotation should not only focus on varying active ingredients but should prioritize using insecticides with different modes of action (Jiang *et al*., 2015; Gong *et al*., 2013; Tarwotjo *et al*., 2014; Prabaningrum *et al*., 2013).

CONCLUSION

The mortality rates of *P. xylostella* larvae from the F1 generation (field population) treated with different doses of deltamethrin, emamectin benzoate, and profenofos were relatively low at doses of 1.5 ml/l, 2.0 ml/l, and 2.5 ml/l, yielding the following results: deltamethrin 16.67%, 33.33%, 36.67%; emamectin benzoate 16.67%, 30.00%, 46.67%; and profenofos 13.33%, 26.67%, 46.67%. However, for the F5 generation (laboratory population), the mortality rates were significantly higher at the same doses, showing the following results: deltamethrin 73.33%, 93.33%, 96.33%; emamectin benzoate 76.67%, 93.33%, 100.00%; and profenofos 76.67%, 90.00%, 100.00%. Resistance in *P. xylostella* controlled with deltamethrin was observed to be 2.15 times, with emamectin benzoate at 2.17 times, and with profenofos at 2.06 times.

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