A Short Review Potential Biopesticide for Managing Pest of Shallot *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae)

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1. Abstract

The beet armyworm (*Spodoptera exigua* Hübner) are the main pests of shallot plants in every growing season. The high attack of *S. exigua* in the vegetative phase yields a massive loss of up to 100%, causing inefficient farming. Synthetic insecticides have been extensively applied for pest management agriculture. However, this practice has been reported to cause environmental pollution, target organism resistance, and non-target organisms destruction. Researchers have paid a lot of serious attention and effort to develop biopesticides that can replace synthetic pesticides. This paper reviewed the use of several botanical biopesticides for controlling *S. exigua*, including *Pangium edule*, *Derris elliptica*, *Alpinia galanga*, *Delphinium naviculare*, *Ocimum basilicum*, and *Rosmarinus officinalis*. The review focuses on effectiveness, active compound content, and mode of action as a pesticide of each botanical biopesticide discussed.

2. Keywords: *Allium cepa* L., *Spodoptera exigua* Hübner, Biopesticides

3. Introduction

Shallots (*Allium cepa* L.), one of the significant horticulture commodities, are distributed in almost all Indonesian regions. Shallots are still suffering from many pests, including beet armyworms (*Spodoptera exigua* Hübner), and cause low productivity. The losses caused by beet armyworms vary widely, ranging from 32%-62.98%, depending on larvae's density [1]. The high level of losses caused by beet armyworm is supported by these insects' ability to attack shallots from the vegetative phase to the ready-to-harvest phase [2]. Decreased quality of shallot yields due to beet armyworms attack in the form of small and white tubers [3-4]. Strategies widely used to control beet armyworms' pest attack are sex pheromones, the application of agricultural systems, and insecticides.

The active ingredients of insecticides commonly used to control beet armyworms in Indonesia, especially on Java island, are hydrochloride, deltamethrin, methoxy phenoxide, and phyraclotose [5-6]. Excessive use of insecticides causes environmental pollution, health problems for farmers and consumers. Besides, it can cause an imbalance of the ecosystem by killing populations of non-target species, the loss of predators, and pest parasitoids, which indirectly facilitate pests causing more significant losses [7-8]. Another problem caused by excessive insecticide spraying is that it causes resistance to beet armyworms because it is sprayed two to three times a week. Insecticide resistance to Spodoptera was reported by Zheng [9] has occurred. Armyworm resistance to methoxyphenoside has been reported in shallot production centers in Java island with an LC50 between 0.53 ppm -127.61 ppm [4-5]. Armyworms were also resistant to indoxacarb, spinosad, and emamectin benzoate [4,10].

Reducing insecticides' negative impact can be done by developing an environmentally friendly approach to reducing insect pest populations, for example, by exploring natural ingredients from plants as natural insecticides. Natural insecticides are widely developed because the degradation of bioactive compounds is faster than synthetic ones. They do not cause residues in nature and consider it safer for use before harvesting due to their nonphytotoxic character [11]. Many plant extracts function as repellents, antifeedants, insecticides, fungicides, nematicides, and molluscicides. The most promising plants and the most widely used natural insecticides come from the Meliaceae, Rutaceae, Asteraceae, Annonaceae, Lamiaceae, Aristolochiaceae, and Malvaceae families [12].

Research on the use of bioactive compounds from secondary metabolites as biopesticides of beet armyworms *S. exigua* has been widely studied. Some of the plants that have been investigated show the main activity and has a high potential to be further developed as biopesticides, including research using four extracts of local minahasa plants (*Pangium edule*, Ricinus communis, Zingiber officinale, *Derris elliptica*), *Alpinia galanga*l, *Ocimum basilicum*, and *Rosmarinus officinalis* [13-15].

a. Shallots (*Allium cepa* L.)

Shallots belong to the Amaryllidaceae family, have shallow adventive fibrous roots, bulbs, and tube-shaped leaves. Shallots have flowers such as umbel (a collection of flowers at various development stages) [16]. Shallots tubers have different morphology compared to other groups of onions. When compared to an onion, shallots have a smaller tuber size. The results explained that shallot tubers are composed of several layers of fleshy parts with an enlarged base and covered by a dry outer layer. Structurally, tubers are a modification of underground stems and leaves. Shallot tubers have various shapes ranging from oval, globe, ellipse, to spindle [17].

Shallots require special agroclimatological conditions to grow, overcome tuber dormancy, initiate seed development, and reproduce [18]. Though it may need a specific condition, shallots are grown in cold to temperate climates. Shallots originate from West Asia, and currently, shallots have become an important horticulture commodity in Africa, Europe, Asia, and the Americas. In Indonesia, shallots are produced in many provinces with production centers in Central Java, East Java, West Java, North Sumatra, West Sumatra, Bali, West Nusa Tenggara, and South Sulawesi. Siagian [19] stated that Java island contributes 76.03% of the total shallot production in Indonesia, where Central Java and West Java recorded as the highest productivity.

b. Spodoptera exigua Hübner (Lepidoptera: Noctuidae)

The beet armyworm (*Spodoptera exigua* Hübner) (Lepidoptera: Noctuidae) is a polyphagous pest that attacks various vegetables and ornamental plants. The beet armyworm consumes almost all parts of the host plant [20]. Beet armyworms are reported to be the primary pest of shallot in Indonesia, onions, and tobacco in India, cotton in Egypt, maize pests in Turkey, and onions in the Philippines [21]. In Indonesia, the beet armyworm infects many shallot plants and has become a problem in shallot plantations [3-4]. The attack of beet armyworm, especially in Indonesia, can reduce production so that the yield is not optimal and results in a deficit of shallot supply in several regions.

The first infestation of beet armyworm caterpillars on shallots can damage plants up to 44.72%, and at a later stage, the damage can increase to 81.90% depending on the density of larvae. There are 5-8 larvae/leaf folds at the infestation peak [22]. The beet armyworm infestation at an early stage will eat away at the inside of the leaves. Larvae that eat leeks will produce skeletonization on the leaves and produce irregular holes [21].

Several strategies to control *S. exigua* have been carried out through manual control, use of sex pheromones, shade nets, and baculovirus (for example, *Spodoptera exigua* Nuclear Polyhedrosis Virus (SeNPV)), entomopathogenic fungi, fertilization, mulch, and insecticide. The use of shade nets and SeNPV to control *S. exigua* has been carried out by [23]. The results show that shade nets reduce damage caused by pests and reduce the amount of insecticide sprayed up to 100%. The SeNPV application can also reduce pest damage by 38.46% compared to manual control.

Another control that has been done is the use of sex pheromones. Research on efforts to control *S. exigua* in Indonesia using sex pheromones has been conducted by [4]. The study examined the use of sex pheromones in two shallot growing seasons, and the results showed that male beet armyworms were found throughout the growing season of shallots. It can be concluded that the successful use of sex pheromones in the cultivation of shallots to date is still limited.

Control of beet armyworm in Indonesia is also carried out by regular spraying of insecticides. Some of the active ingredients of insecticides commonly used to control beet armyworm in Indonesia, especially in Java Island, are hydrochloride, deltamethrin, methoxy fenozide phyraclotose [5-6]. Excessive use of insecticides can cause beet armyworm resistance to insecticides, cause harm to consumers and manufacturers, disrupt the population of other insects around the area, and cause chemical residues on shallots. Resistance can occur due to the use of inappropriate, too frequent, and excessive doses of insecticides, mixing of various types of insecticides, and insects have developed a defense or adaptation mechanism so that they are more resistant to insecticides. So it is necessary to develop safer control methods for alternative environments to reduce the use of insecticides. One of them is with the development of botanical insecticides. Therefore it is necessary to examine the potential of one of the compounds of plants in the beet armyworm control.

c. Biopesticide potential in controlling *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae)

Natural insecticides are categorized into botanical insecticides and microorganisms such as fungi, viruses, and nematodes that cause disease in certain insects. Botanical insecticides are insecticides whose active ingredients are extracted from plants. In this discussion, the potential of botanical insecticides will be examined.

The use of botanical insecticides in pest control of beet armyworm has been widely developed, including research using alkaloids isolated from all parts of the plant *Delphinium naviculare* var. lasiocarpum, as an antifeedant larva of *Spodoptera exigua* (Hübner) [24]. Research using four extracts of local minahasa plants (*Pangium edule*, Ricinus communis, Zingiber officinale, *Derris elliptica*), the study showed that P. edule seed extract and D. elliptical root extract efficiently act as larvacide and antifeedant. In the study, it was known that shawurensine compounds showed quite strong antifeedant activity with EC50 0.42 and 0.81 mg/cm^2 in the test choice and no choice [13]. Yooboon [14] investigated the toxicity of crude extracts and phenylpropanoid compounds A. galanga against *S. exigua*. After 24 hours, the application of the ethyl acetate extract of A. galanga on the feed showed toxicity to the larvae of *S. exigua* with LD50 ~ 2.44 µg/larva.

Insecticidal activity of Salvia Veneris Hedge essential oil against coleopteran and *Spodoptera exigua* insects showed contact toxicity of 63.0% against 3rd instar larvae of *S. exigua* at 100 µL /Ml [25]. Murcia-meseguer [15], reported that the toxicity of *Ocimum basilicum* oil significantly reduced the fecundity of *S. exigua* by 142.89 ± 45.99 (eggs/female, week).

The development of pest control using bioactive compounds from plants is a promising strategy in reducing the negative impact of excessive use of insecticides. The success of biopesticide development can be improved if there is information about the bioactive compounds and how they act against the target insect. Research on the use of biopesticides from plants in pest control has been widely carried out-research on biopesticides in the control of shallot caterpillars that have been done previously.

Goniothalamin styryl-pyrone isolated from Goniothalamus wightii Hook. f. and Thoms, on *S. exigua*, a bioassay test showed that goniothalamin had a strong effect on food utilization, molting, and intestinal histology [26]. Alkaloids isolated from all parts of the *Delphinium naviculare* as an antifeedant larva of *S. exigua* (Hübner). The shawurensine compound showed quite strong antifeedant activity (EC50=0.42 and 0.81 mg/cm^2 [24]. Alkaloid diterpenoids of two Aconitum Species with antifeedant activity against Spodoptera exigua, chasmanthinine showed a strong antifeedant activity with an effective concentration for 50% (EC50) at 0.07 mg/cm^2 [27].

Study of alkane isolates and crude extracts from Sphagneticola trilobata as candidates for botanical insecticides for *S. litura*, *S. exigua*, Plutella xylostella. The results showed that the S. trilobata extract had contact toxicity against the pest [28]. Effects of sublethal concentrations of tomato and potato leaf extracts on *S. exigua*. The two extracts exert a similar effect in the cells of the middle intestine and fat body cells. Midgut cells did not change significantly, while fat body cells showed swelling of the nuclear membrane and endoplasmic reticulum becoming prominent, mitochondrial vacuolization, and fat droplet fusion [29]. Effects of traditional medicinal plant extracts, harmaline (H), and ricinine (R) individually or in combination with Bacillus thuringiensis (Bt) cause acute toxicity effects and sublethal effects on the nutrition and enzyme systems of *S. exigua* [30].

Effect of extracts from Peganum harmala and Ricinus communis on glutathione S-transferase activity in body fat and middle intestinal tissue of *S. exigua* at different exposure times [31]. Antifeedant and phagostimulant activity of extracts and pure compounds of Hymenoxys robusta in *S. exigua* larvae, compounds extracted from H. robusta effectively reduce the eating behavior of *S. exigua* in the test without preference [32]. The activity of Melia azedarach extract against *S. exigua*, after exposure to CRU and LIM, hatching success was slightly lower, larval and pupa-imago turnover was significantly impaired. In physiological studies, CRU extract lowered the heart of *S. exigua* [33].

5. Conclusion

Synthetic insecticides that have been used causes environmental pollution, resistance, and non-target organisms destruction. Efforts to control beet armyworms are safe by using biopesticides. The development of biopesticides in controlling *S. exigua* has been developed, some of which are botanical biopesticides from *Pangium edule*, *Derris elliptica*, *Alpinia galanga*, *Delphinium naviculare*, *Ocimum basilicum*, and *Rosmarinus officinalis*

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