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Efficacy of Botanical Insecticide Nanoemulsion Based on *Tephrosia vogelii* against Aphid Pests on Broccoli Plants

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Abstract. Aphids (*Aphis gossypii)* are a potential pest on broccoli plants (*Brassica oleracea*). The use of insecticides made from *Tephrosia vogelii* using nanoemulsion technology offers an environmentally friendly solution for this pest control. Nanoemulsion technology can produce very small particle sizes of nanometers that are adsorbed in liquids so that insecticides are more stable and effective. This study aims to test the effectiveness of botanical insecticide nanoemulsion made of *Tephrosia vogelii* against aphid pests on broccoli plants in the field. The research was carried out in the field, and the dose of field application refers to the results of laboratory research training (Tama, 2018). This study consisted of 4 treatments and six replicates, including K (Control), NTv (Nanoemulsion of vegetable insecticide made from *T. vogelii*), BT (bioinsecticide *Bacillus thuringiensis),* IS (synthetic insecticide with the active ingredient *Abamectin*). The results showed that the effectiveness of the three treatments included NTv 40.52%, BT 23.26%, IS 9.69%. There was a decrease in aphid populations in all three treatments. NTv (vegetable insecticide nanoemulsion made from *T.vogelii*) had the highest effect on aphids in broccoli plants in the field.

Keywords: Nanoemulsions, vegetable insecticides, *Tephrosia vogelii*, aphids, potential pests

INTRODUCTION

Broccoli plant (*Brassica oleracea L.)* is a horticultural vegetable with high economic value. However, pest attacks such as aphids (*Aphis gossypii*) are often a major problem in production, as these pests can damage leaves, inhibit photosynthesis, and decrease crop yields (Huang et al., 2021). Pest control is usually carried out using synthetic chemical insecticides, but this method has risks such as pest resistance, harmful residues, and adverse environmental impacts (Isman, 2020). Therefore, the search for more environmentally friendly and sustainable alternatives is a priority.

A natural insecticide based on *Tephrosia vogelii* offers a potential solution because it contains rotenoid compounds that are effective as natural insecticides (Mwangi et al., 2019). Some studies have shown that plant-based insecticides have a smaller environmental impact than synthetic insecticides. *Tephrosia vogelii* is a type of leguminose containing rotenoid compounds such as rotenones that act as antifeedant and neurotoxic compounds in insects (Belmain et al., 2012). These compounds inhibit electron transfer in the mitochondrial respiratory chain, causing paralysis in target insects (Scott et al., 2020). However, plant extracts in conventional formulations often have limitations such as low stability and solubility, which affect their effectiveness when used in the field (Speranza et al., 2019).

Nanoemulsion technology comes as an innovation that can overcome this shortcoming by improving the stability, bioavailability, and effectiveness of the active ingredient thanks to its very small particle size, ranging from 20-200 nm (Salvia et al., 2022). The use of nanoemulsion technology in formulating plant-based insecticides has been proven to overcome this challenge. Small nanoparticles can penetrate the insect cuticle layer more efficiently, thereby increasing the bioactivity of active ingredients (Ali et al., 2020). This technology also extends the active life of insecticides in the environment because they are more resistant to degradation due to external factors such as sunlight and rain (Zohar-Perez et al., 2019). Further research is needed to understand the impact of the application in the field and compare it with other pest control methods to support safer and more sustainable agricultural practices.

Nanoemulsion is a dispersion system that combines two liquids that are normally not mixed, using an emulsifier and high energy to produce uniform nanoparticles (Tadros et al., 2021). In insecticides, nanoemulsion formulations increase the absorption of active ingredients by insect cuticles and improve adhesion to plants, so that insecticides become more effective and stable in the field (Kah et al., 2021). With this formulation, insecticides can be more efficient at lower doses, reduce environmental impact, and reduce the risk of insect resistance. This study aims to evaluate the effectiveness of nanoemulsion-based botanical insecticides with the active ingredient *T. vogelii* in controlling aphid populations in broccoli plants in the field. The study also compared the effectiveness of nanoemulsions with the bioinsecticide *Bacillus thuringiensis* and the synthetic insecticide *abamectin*.

LITERATURE

Using synthetic chemical insecticides has various negative impacts, such as pest resistance, harmful residues, and environmental damage (Isman, 2020). Alternatively, Tephrosia vogelii-based plant-based insecticides offer an advantage because they contain neurotoxic and antifeedant rotenoid compounds, which are able to control various types of pests (Mwangi et al., 2019; Mlozi et al., 2022).

However, conventional formulations of plant-based insecticides often have limitations, such as low stability and bioavailability in the field (Fernando, 2022; Speranza et al., 2019). Nanoemulsion technology can improve the efficacy of insecticides by improving the stability and effectiveness of active ingredients (Salvia et al., 2022). Nanoemulsion particles are able to penetrate the insect cuticle layer with high efficiency and are more resistant to environmental degradation, such as exposure to UV light and rain (Tadros et al., 2021; Kah et al., 2021).

Previous research has also shown that nanoemulsion-based insecticides can significantly improve pest control compared to conventional methods (Zhao et al., 2019; Ali et al., 2020). In this study, the formulation of a nanoemulsion with the active ingredient T. vogelii was compared with a bioinsecticide made from Bacillus thuringiensis and a synthetic insecticide made of abamectin to determine the level of efficacy in the field.

The application of nanoemulsion technology showed positive results in reducing Aphis gossypii's aphid population, especially with T. vogelii-based treatments, which provide an environmentally friendly and effective solution for sustainable agricultural practices (Huang et al., 2021; Zhang et al., 2020).

METHOD

Location

This research was conducted in Nagari Batang Barus, Gunung Talang District, Solok Regency. The preparation of raw materials and the manufacture of vegetable insecticide extracts were conducted at the Insect Bioecology Laboratory, Department of Plant Protection, Faculty of Agriculture, Andalas University, Padang. This study was experimental with a Group Random Design (RAK) consisting of 4 treatments and six replicates. The treatment consists of K = Control (No Treatment). NTv = Nanoemulsion of Tephrosia vogelii leaf extract. BT = Bioinsecticide (Thuricide with active ingredient: Bacillus thuringiensis). IS = Synthetic Insecticide (Instop 311 EC with active ingredient Sipermethrin 311g/l).

Land Cultivation

Land cultivation is carried out by clearing agricultural land from shrubs and grasses that grow wild on the agricultural land used as a research location. The land was mapped with 24 experimental plots, each measuring 14 m x 1.1 m. Fertilize the bottom with manure by spreading it evenly on the beds. Plastic mulch is installed to cover the surface of the beds.

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All beds are covered with mulch and given planting holes with a 5-8 cm diameter and a planting distance of 70 cm x 50 cm (Directorate of Fertilizers and Pesticides, 2012).

Broccoli Planting and Sample Plant Determination

Seeds are obtained by buying from farmers in Nagari Koto Laweh with the Green magic variety. Seedlings used with the criterion of being 2-3 weeks old after sowing have a height of about 12-15 cm from the base of the stem and are free from pests and diseases. The seedlings were transferred to the research land. Seedlings are planted in each hole, and one seedling is perforated at a distance of 70 cm x 50 cm. The number of plants on each map is 60 plants. The total number of broccoli seedlings planted on the land amounted to 1,440 seedlings. The determination of sample plants was carried out randomly and systematically. Each bed consists of 6 sample plants.

Preparation of Vegetable Insecticide Raw Materials

The main ingredient for making plant-based insecticides is the leaves of Tephrosia vogelii obtained from Nagari Sungai Sikai, Gunung Tujuh District, Kerinci Regency, Jambi Province. The leaves of T. vogelii used as a vegetable insecticide are selected for purple flowering, leaves that are not too old and not too young, and are free from pests and diseases. The leaves of T. vogelii are separated from the twigs and placed on a tray that has been lined with paper. T. vogelii leaves are dried without direct sunlight until the leaves are completely dry (7-14 days). Dried leaves, chopped with a shredder. The chopped results are mashed with a blender. The results of the blended leaves are sifted with a sieve with a diameter of 0.5 mm so that T. vogelii is obtained in powder form.

Preparation of comparator insecticide raw materials

(Synthetic and bioinsecticide) Synthetic insecticides and bioinsecticides BT (*Bacillus thuringiensis*) as comparative treatments were obtained by purchasing them at agricultural stores in Pasar Raya Kota Padang. Instop synthetic insecticide with cypermethrin 311g/l, while BT insecticide with the active ingredient Bacillus thuringiensis. Synthetic insecticides and bioinsecticides are then taken to the field to be diluted. The dilution process is carried out under the Standard Dilution Procedure contained in the label. Instop 311 EC synthetic insecticide with a recommended concentration of 1 ml/liter and BT bioinsecticide with a recommended concentration of 1 gr/liter.

Tephrosia vogelii Extraction

T. vogelii extraction begins with maceration. The maceration method is that 100 grams of *T. vogelii* powder is soaked with 1,000 mL of ethyl acetate with a ratio of 1:10

(Abizar & Prijono, 2010) for 3 x 24 hours (Handoyo, 2020). The results of maceration were filtered 2 times. First is a funnel with a diameter of 20 cm, lined with ordinary filter paper and accommodated with Erlenmeyer. Second, the results of the first filter were filtered again based on Whatman paper no—41, which was accommodated with an airtight bottle measuring 1 liter. A rotary evaporator evaporates the result of the second filter at a temperature of 45^0 C and a pressure of 227 mbar. The obtained ethyl acetate solution is reused to re-soak the pulp of plant extracts until 3x soaking. The extract obtained is then transferred into a 100 mL vial bottle and stored in a 4ºC refrigerator until use (Lina et al., 2013).

Nanoemulsion Manufacturing

PT Nanotech Asa Peduli, Serpong, South Tangerang, manufactures nanoemulsions using a nanoemulsion-making machine on a liter scale (Nanoemulsifier).

Field Applications

The application of insecticides is carried out in the morning (07.00–10.00 WIB) or in the afternoon (16.00–18.00 WIB) using a Knapsack sprayer with an interval of one week. In the application of vegetable insecticides, a concentration level determined based on the results of toxicity tests in the laboratory is equivalent to 2 x LC95 of 2.18% in the control of main caterpillar pests. LC95 is the main pest which is 1.09%. The number of applications in the field in the efficacy test is at least 6 times and a maximum of 2 weeks before harvest (Directorate of Fertilizers and Pesticides, 2012). The application of the comparator insecticide was Thuriside HP (ba: *Bacillus thuringiensis*) with a recommended concentration of 1 ml/liter and the synthetic insecticide Instop (ba: cypermethrin 311g/l) with a recommended concentration of 1 ml/liter. The need for a large volume of spray solution in each treatment is 2 liters at 21 HST, 28 HST to 42 HST as much as 5 liters, and at 49 HST to 70 HST as much as 10 liters.

DISCUSSION

Aphids (*Aphis gossypii*) are classified as potential pests on vegetable crops (*Brassicae*). *A. gossypii* is known to have rapid reproduction ability and high adaptability to the environment, so it requires effective control methods (Blackman & Eastop, 2021). The population of *A. gossypii* begins to be found in the 2nd week after planting. The peak of population reached 87.44±54.18 (Average ± SD) in the 4th week after planting. Wasonawati (2019), in her study, concluded that broccoli plants in the 4th week after planting gave the largest fresh flower weight, and the 5th week of seedling age after planting produced the highest growth, width, and diameter of stems compared to all observation ages.

This shows that proper population control *of A. gossypii* is very important to maintain the quality and quantity of broccoli crops. Therefore, in this planting period, control strategies need to be optimized to increase optimal crop yields (Susilo et al., 2021; Nur et al., 2020). Applying vegetable insecticide nanoemulsions made from *T. vogelii* can reduce the population of *A. Gossypii*. The decline in the population *of A. gossypii* in the 1st to eighth week after planting is as follows:

Aphid Population (*Aphis gossypii)*

Table 1. Aphid pest population (*Aphis gossypii)* in observing 1-4 broccoli plants after being treated with several types of plant insecticides.

Treatment	Aphid pest population (*Aphis gossypii)* (Average ± SD)			
	P1	P2	P3	P4
K	0,00±0,00 A	1.49±1.09 A	1.13±0.95 A	1.26±1.85 b
NTv	0,00±0,00 A	0.01±0.05 A	0,00±0,00 A	0.88±1.49 b
BT	0,00±0,00 A	1,96±1,08 A	0.21±0.73 A	4.47±3.32 b
IS	0,00±0,00 A	0.33±0.20 A	1.50±0.78 A	87.44±54.18 A

Table 2. Aphid pest population (*Aphis gossypii)* in observing 5-8 broccoli plants after being treated with several types of vegetable insecticides.

Treatment	Aphid pest population (*Aphis gossypii)* (Average ± SD)			
	P5	P6	P7	P8
K	6.51±9.46 ab	6.10±9.32 b	5.04±6.45 b	0.32±0.78 b
NTv	1.38±1.32 b	5.15±4.69 b	6.11±5.33 b	2.18±2.00 b
BT	1.96±4.56 b	6.29±6.11 b	1.35±1.88 b	3.36±4.16 ab
IS	33.39±34.50 A	50,40±57,06 A	42.29±43.56 A	8.54±7.72 A

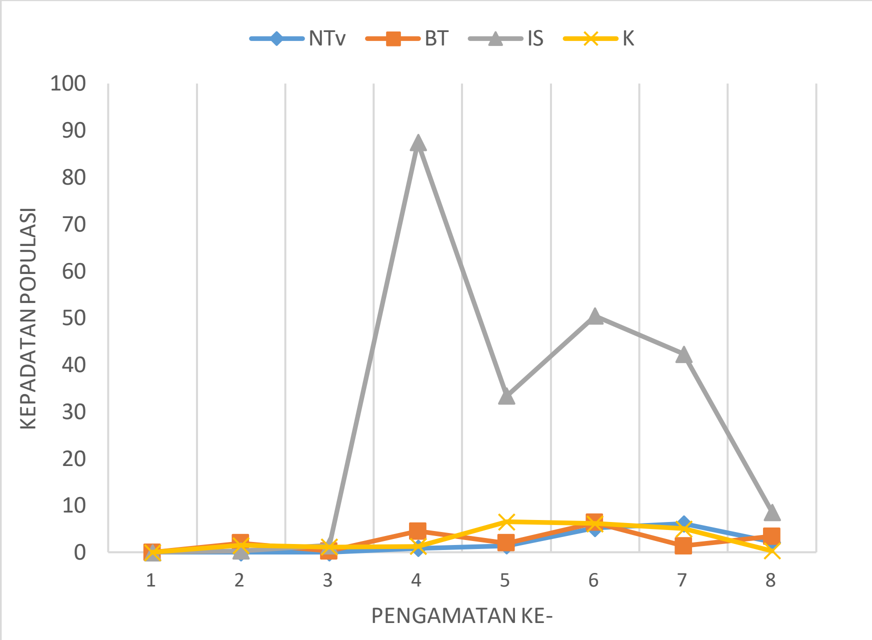

Figure 1. Graph of Aphid Pest Population Development (*Aphis gossypii*) on broccoli plants after being treated with several types of insecticides

A significant decrease in aphid populations in NTv treatment shows the superiority of insecticides made from *T. vogelii* in pest control (Mwangi et al., 2019; Isman, 2020; Huang et al., 2021; Zhao et al., 2019; Pereira et al., 2023). *T. vogelii* contains rotenoid compounds that act as neurotoxins that can disrupt the nervous system of insects and cause death (Mwangi et al., 2019; Tadros et al., 2021; Kah et al., 2021; Salvia et al., 2022; Zhang et al., 2020). The combination of the active ingredients contained in *T. vogelii leaves* and nanoemulsion technology provides an increase in the bioeffectiveness of this plant-based insecticide in the field (Salvia et al., 2022; Patel & Karve, 2018; Lopes et al., 2020; Kah et al., 2021; Mwangi et al., 2019).

Insecticide effectiveness

Table 1. Effectiveness of Insecticide Nanoemulsion made of *T.vogelii* to Control Aphid Pests

Treatment	Observation to- (%)								
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	∑
NTv	00,00	99,06	100	30,76	78,89	15,48	00,00	00,00	40.52
BT	00,00	00,00	81,48	00,00	31,34	00,00	73,27	00,00	23.26
IS	00,00	77,57	00,00	00,00	00,00	00,00	00,00	00,00	9.69

The results showed that the use of vegetable insecticide nanoemulsion made of *T. vogelii* (NTv) had a higher efficacy rate in reducing the population of *A. gossypii* in broccoli plants compared to the bioinsecticide *B. thuringiensis* (BT) and synthetic insecticides made of *abamectin* (IS). The highest efficacy was shown by NTv treatment with an average of 40.52%, followed by BT at 23.26%, and IS at 9.69%.

Nanoemulsions made from *T. vogelii* (NTv) can increase the effectiveness of active ingredients in controlling pests (Zhao et al., 2019; Huang et al., 2021). NTv has a very small particle size, which allows for better penetration into the insect cuticle and improves the stability and efficiency of insecticides in the field (Salvia et al., 2022; Tadros et al., 2021; Kah et al., 2021; Lopes et al., 2020; Patel & Karve, 2018). Nanoemulsion technology expands the contact area between the active ingredient and the leaf surface, increases the absorption of insecticides by pests, and reduces volatility so that the compound is more durable in the environment (Kah et al., 2021; Salvia et al., 2022; Huang et al., 2021; Mwangi et al., 2019; Zhang et al., 2020).

Overall, the use of NTv as a nanoemulsion-based plant-based insecticide shows excellent potential in controlling *Aphis gossypii* populations in broccoli plants (Salvia et al., 2022; Huang et al., 2021; Isman, 2020; Mwangi et al., 2019; Tadros et al., 2021). This technology not only provides an environmentally friendly solution but also reduces the risk of chemical residues and negative impacts on ecosystems (Kah et al., 2021; Salvia et al., 2022; Patel & Karve, 2018; Lopes et al., 2020; Huang et al., 2021). The development and use of nanoemulsion technology in the formulation of plant-based insecticides can be a strategic step in sustainable pest control in the future (Tadros et al., 2021; Zhang et al., 2020; Isman, 2020; Mwangi et al., 2019; Kah et al., 2021).

The results of the study also indicated that synthetic insecticides made of abamectin (IS) had the lowest efficacy, with a population decline of only 9.69% (Huang et al., 2021; Zhao et al., 2019; Isman, 2020; Pereira et al., 2023; Tadros et al., 2021). This may be due to the presence of resistance in aphid populations to the insecticide (Zhang et al., 2020; Huang et al., 2021; Kah et al., 2021; Salvia et al., 2022; Lopes et al., 2020). The phenomenon of resistance has been reported as one of the major drawbacks of the continuous use of chemical insecticides (Isman, 2020; Tadros et al., 2021; Zhao et al., 2019; Zhang et al., 2020; Lopes et al., 2020).

On the other hand, the bioinsecticide *Bacillus thuringiensis* (BT) shows moderate efficacy. Although it has the potential as an environmentally friendly alternative, its effectiveness depends on environmental conditions and compatibility with certain pest species (Huang et al., 2021; Isman, 2020; Kah et al., 2021; Salvia et al., 2022; Zhang et al., 2020). *B. thuringiensis* produces endotoxin proteins that can interfere with digestion *A.*

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Gossypii However, the effectiveness of this bioinsecticide is greatly influenced by various environmental conditions, such as temperature, humidity, and exposure to ultraviolet light. Other studies show that sunlight can break down BT toxins, reducing their active life in the field (Isman, 2020; Kah et al., 2021; Salvia et al., 2022).

In addition to environmental factors, BT's suitability to certain pest species is also important to consider. Some pest populations show different tolerance levels to BT proteins, which are often associated with the development of insect resistance. Therefore, implementing BT should be accompanied by an integrated pest management strategy (IPM) to maintain its long-term effectiveness (Huang et al., 2021; Zhang et al., 2020). For example, combining BT with other biological control methods, such as utilizing natural predators, has been shown to increase the success of pest control while maintaining the balance of the ecosystem (Isman, 2020).

CONCLUSION

Insecticide nanoemulsion based on *Tephrosia vogelii* effectively controls aphid pests in broccoli plantations. Nanoemulsion technology has been proven to improve the stability and effectiveness of insecticides. The use of vegetable insecticide nanoemulsion made from *T. vogelii* (NTv) has high effectiveness in controlling aphid populations (*A. gossypii*) in broccoli plants in the field. NTv treatment resulted in a significant decrease in the pest population compared to bioinsecticides made from *Bacillus thuringiensis* (BT) and synthetic insecticides with active ingredients cypermethrin (IS). The effectiveness of NTv reached 40.52%, higher than BT with 23.26%, and IS, which showed lower effectiveness of 9.69%.

This indicates that nanoemulsions made from *T. vogelii* can be a more environmentally friendly and effective pest control alternative, reduce the risk of resistance, and reduce harmful chemical residues in plants. This research makes an important contribution to developing environmentally friendly pest control methods using natural materials, besides improving the efficiency and safety of modern agricultural cultivation practices. This research is expected to encourage further research on applying nanoemulsions to control other pests, improve the competitiveness of local technologies in the agrotechnology sector, and support the development of safer and more sustainable agriculture.

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