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The effectiveness of star anise nanoemulsion and chemical insecticide for controlling of beet armyworm

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Abstract The effectiveness of star anise (*Illicium verum*) nanoemulsion and deltamethrin (chemical insecticide) was tested with beet armyworm (*Spodoptera exigua*) to evaluate their mortality, antifeedant, and growth inhibition effects at proper concentrations. As a result, at the obtained highest effectiveness, star anise nanoemulsion required 0.35% concentration for the maximum effectiveness with 100% mortality, antifeedant and growth inhibition effects against beet armyworm, when compared with the control (Tween20 and water), while deltamethrin exhibited a lower rate. Therefore, star anise nanoemulsion seem to be utilized as a highly effective and environmentally friendly insecticide to control beet armyworm.

Keywords: Mortality, Antifeedant, Growth inhibition, Nanoemulsion, Beet armyworm

Introduction

The beet armyworm (*Spodoptera exigua*) is the major pest of cruciferous vegetables and Welsh onion (Ueno, 2006). These larvae fed leaves of cruciferous crop. It caused serious damage in Thailand. The main problem of management in the beet armyworm was insecticide resistance because it had developed resistance to chemical insecticides (Su and Sun, 2014). Additionally, the chemical insecticides had insecticide residue in the environment and pollution to the ecosystem. These were a negative effect on non-target organisms and mammals (Ondieki, 1996). Using the chemical insecticides in long term could be increase in insecticidal resistance and made it difficult to controlling insect pest (Ortega *et al.*, 2021). The present, some farmers used botanical insecticides instead of chemical insecticides for reduce the negative effect. Botanical insecticides could be controlled insect pests and plays as eco-friendly method (Patel *et al.,* 2022). Botanical insecticides had the insecticidal effective such as mortality, antifeedant, growth inhibition and it can reduce insect pest resistance

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(Mochiah *et al.,* 2011). The plant essential oil nanoemulsion is used as alternative choice for agriculturist. The previous studies showed that the star anise EO played as growth inhibites in gypsy moth (Kostić *et al.,* 2021). At the low concentration of star anise had increased the acetylcholinesterase and glutathione S-transferease enzyme which were the specific mechanism of toxicity in insect pests (Peter *et al.,* 2022). Star anise EO had high insecticidal effect on larva and adult stage of *Callosobruchus chinensis*, *Botrytis cinerea* and *Colletotrichum gloeosporioides* (Shukla *et al.*, 2009). Star anise EO contained 81.4% of trans-anethole, 6.5% of limonene, 2.1% of chavicol (Gholivand *et al.*, 2009). Trans-anethole was main chemical compound in star anise EO. It had high inhibited of acetylcholinesterase activity in *Cryptolestes ferrugineus* (Wang *et al.,* 2021). So, tran-anethole in star anise EO was highly effective against insect pest (Hikal *et al.,* 2017).

The plant essential oil used as botanic insecticides which had low toxicity to environment. However, it was easily degraded by air, light and temperature. Therefore, essential oil nanoemulsion (nEO) increased disadvantages of EO (Isman, 2020). The formulation of nanoemulsions had the small particle size, stable, low volatility and solubility property and performed high insecticidal property (Noichinda and Suppavorasatit., 2019). This study implied how using plant essential oil nanoemulsion and chemical insecticides in controlling beet armyworm.

Materials and methods

Insect culture

The samples of beet armyworm were collected from Chinese cabbage plot in Nakhon Pathom, Thailand. After that, they were reared in boxes at room temperature (25±2 ◦C) and 12:12 light-dark cycle, at School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand.

Chinese cabbage cultivation

Chinese cabbages were cultivated (non insecticides) for beet armyworm food in greenhouse at School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand.

Essential oil nanoemulsion (nEO) preparation and mortality efficacy test in laboratory conditions

Star anise was prepared for nanoemulsion using aqueous titration method. The star anise was diluted with surfactant (Tween 20) and water. The first selected star anise nanoemulsion was observed with naked eyes. It was nonsediment, nonseparation and got a homogeneous emulsion. Star anise nanoemulsion was used to measure particle sizes with a particle analyzer. The star anise nEO particle sizes anslysis was found to be smaller than 100 nm.

In no choice test, the star anise nanoemulsion and Deltamethrin (chemical insecticide) were tested against beet armyworm when the mortality rate was observed at 24 hours at appropriate concentrations of star anise nanoemulsion and deltamethrin by using leaf dipping method. The second larval stage of beet armyworms were put in box. The mortality rates were calculated using Abbott's formula (Abbott, 1925). The different contrations of star anise nEO was tested against the beet armyworm as follows: T1: Control (0.35% Tween 20 and water), T2: 0.25% Star anise nEO (SAnEO), T3: 0.35% Star anise nEO (SAnEO), T4: Deltamethrin insecticide (DI) recommended dose (0.35%), T5: DI (half recommended dose 0.35%) + SAnEO (0.15%), T6: (half recommended dose 0.35%) + SAnEO (0.25%).

Antifeedant efficacy test in laboratory conditions

This experiment was performed as mentioned in mortality efficacy test. The feeding area happened in leave was measured when compared with control group. As for the choice test, it was prepared as the same as no choice test, whereas each treatment was placed in the opposite site with the control in circle box. The percentage of antifeedant activity was calculated using antifeedant index (AFI) (Escoubas *et al.,* 1992).

Growth inhibition efficacy test in laboratory conditions

This experiment was also investigated following the mortality efficacy test when the development of larva to be pupa and pupa to be adult of beet armyworms were observed and recorded.

Statistical analysis

In this study, Abbott's formula was applied to obtain the beet armyworm mortality rate. The experiment was performed in completely randomized design (CRD) with 3 replicates per treatment. The obtained data were analyzed by ANOVA program.

Results

The mortality efficacy

At 0.35% concentration, star anise essential oil nanoemulsion (SAnEO) had the highest effect that caused 100% mortality of beet armyworm larvae at 24 hours when compared with the control while Deltamethrin insecticide (DI)recommended dose (0.35%) had 91.7% mortality rate as shown in Table 1.

Table 1. The mortality percentage of beet armyworm caused by the various concentration of star anise essential oil nanoemulsions (nEO) and chemical insecticide

Essential oil nanoemulsion / chemical insecticide	Average mortality (%) (Mean ± SD)
Control (0.35% Tween 20 and water)	0.0 ± 0.0^{D}
Star anise nEO (SAnEO)	
0.25%	41.7 ± 0.4^{C}
0.35%	100.0 ± 0.0^{A}
Deltamethrin insecticide (DI) recommended dose (0.35%)	91.7 ± 0.4^{A}
Mixed method	
DI (half recommended dose 0.35%) + SAnEO (0.15%)	45.0 ± 0.6^{C}
DI (half recommended dose 0.35%) + SAnEO (0.25%)	68.3 ± 1.0^{B}

Means in column followed by the same uppercase letter is not significantly different ($P < 0.05$) according to Duncan's multiple range test.

The satisfactory result was obtained when mostly diped leaves with star anise nEO and deltamethrin exhibited 100% antifeedant activity. Only half recommened dose of deltamethrin mixed with 0.15%-star anise nEO (SAnEO) showed lower activities. Therefore, 83.3% antifeedant was found on the choice test and 75.0% antifeedant on no choice test (Table 2).

The star anise nEO at 0.35% and deltamethrin at a recommended rate proposed the complete growth inhibition against the beet armyworm with both larval to pupal and pupal to adult stages of development. The half-recommended dose of deltamethrin mixed with 0.25%-star anise nEO (SAnEO) also gave 100% growth inhibition for the development of pupal to adult stages. Rather low growth inhibitions were found in the treatments of 0.25%-star anise nEO (SAnEO) and half recommended dose of deltamethrin mixed with 0.15%-star anise nEO (SAnEO) (Table 3).

Table 2. The antifeedant percentage caused by the various star anise essential oil nanoemulsions (nEO) and chemical insecticide against the beet armyworm

Essential oil nanoemulsion / chemical insecticide	Average antifeedant (%)	
	The no choice test	The choice test
Control (0.35% Tween 20 and water)	0.0 ± 0.0 ^{C}	0.0 ± 0.0 ^{C}
Star anise nEO (SAnEO)		
0.25%	100.0 ± 0.0^{A}	100.0 ± 0.0 ^{A}
0.35%	100.0 ± 0.0^{A}	100.0 ± 0.0 ^{A}
Deltamethrin insecticide (DI) recommended dose (0.35%)	100.0 ± 0.0^{A}	100.0 ± 0.0 ^{A}
Mixed method		
DI (half recommended dose 0.35%) + SAnEO (0.15%)	75.0 ± 1.9 ^{B}	83.3 ± 0.8 ^{B}
DI (half recommended dose 0.35%) + SAnEO (0.25%)	100.0 ± 0.0 ^{A}	100.0 ± 0.0 ^{A}

Means in column followed by the same uppercase letter is not significantly different ($P < 0.05$) according to Duncan's multiple range test.

Table 3. The growth inhibition percentage caused by the various star anise essential oil nanoemulsions (nEO) and chemical insecticide against the beet armyworm

Essential oil nanoemulsion / chemical insecticide	Average growth inhibition (%)	
	larval to pupal stage	pupal to adult stage
Control (0.35% Tween 20 and water)	0.0 ± 0.0 ^{D}	0.0 ± 0.0 ^{D}
Star anise nEO (SAnEO)		
0.25%	56.7 ± 0.8 ^{C}	68.3 ± 0.8 ^{C}
0.35%	100.0 ± 0.0^{A}	100.0 ± 0.0 ^{A}
Deltamethrin insecticide (DI) recommended dose (0.35%)	100.0 ± 0.0^{A}	100.0 ± 0.0 ^{A}
Mixed method		
DI (half recommended dose 0.35%) + SAnEO (0.15%)	60.0 ± 0.9^{C}	76.7 ± 0.5^{B}
DI (half recommended dose 0.35%) + SAnEO (0.25%)	80.0 ± 0.6 ^{B}	100.0 ± 0.0 ^{A}

Means in column followed by the same uppercase letter is not significantly different ($P < 0.05$) according to Duncan's multiple range test.

Discussion

Chemical insecticide could eliminate insect pests (Dong *et al*., 2007). Deltamethrin is group of synthetic pyrethroid with low toxicity to mammals but high insecticidal effect on insect pests. It has been used in agricultural, public heath and domestic sectors (Falah and Burr., 2023) to eliminate insect pests through contacting and feeding. Mode of action of deltrametrin caused repetitive nerve stimulation (Najera and Zaim, 2001). The previous studies showed the resistance of deltamethrin in red flour beetle as CYP6BQ9 could be hydroxylate deltamethrin at the 4' position expressed in brain and led to resistance (Zhu *et al.,* 2010). High temperature caused low effect and it could be residual effect about 3-6 months. These results showed that deltamethrin had high insecticidal property against beet armyworm in laboratory conditions, but it had lower effects than star anise nEO. This is in line with the fact that the deltamethrin had low mortality effect on the warehouse beetle at 6 and 120 hours (Wallbank, 1994). The experiment of laboratory conditions had high toxicity on honeybee but low toxicity on the field conditions (Johnson *et al*., 2010). At present, the insecticidal effect of delteramethrin was low due to insecticide resistance. In this study, star anise nEO had high insecticidal effect in terms of mortality, antifeedant, repellent and growth inhibition activities against the beet armyworm. Therefore, the star anise nEO could be useful for the control on insect pests. In the future, it can be developed to acheive environment friendly nEO in form of insecticides and it would be used and mixed with chemical insecticides for reducing chemical insecticide used in the large scale on the field, even if, in this study it did not express strong efficiency.

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