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Impact of ginger compound (*Zingiber officinale* Roscoe) as control of brown planthopper (*Nilaparvata lugens* Stal.)

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Abstract

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One of the most critical pests on rice plants is the brown planthopper (*Nilaparvata lugens* Stal.), commonly referred to as BPH. BPH can attack rice at all stages of plant growth, and severe infestations can lead to crop failure. Alternatives to control BPH could be achieved by using plant-based pesticides from *Zingiber officinale* Roscoe in the form of formulations. This study aimed to determine the activity and ability of *Z. officinale* R botanical insecticide formulation and its economic potential for controlling BPH. The study used a completely randomized design (CRD) with seven treatments and four replications. *Z. officinale* R. concentrations used were 0.25%, 0.49% 0.70%, 0.98%, 1.38%, treatment using synthetic pesticides, and control. Data were analyzed using variance (ANOVA), and significant differences were further tested with LSD at the 5% level. Data were processed using the Statistical Package for the Social Sciences (SPSS) software. The results showed that the formulation of botanical pesticides from *Z. officinale* R. could control BPH. Treatment with a concentration of 1.38% was the most effective in killing BPH nymphs by 80%. Application of the *Z. officinale* R. formulation affected the daily mortality of BPH nymphs. BPH nymphs died in rice 1-4 days after application. *Z. officinale* R. formulation affected the number of BPH adults formed. The adults formed were 15% at a concentration of 1.38%.

Keywords: Zingiber officinale; botanical insecticide; formulation; mortality

Introduction

One of the important pests of rice plants (*Oryza sativa* L.) is the brown planthopper (BPH), *Nilaparvata lugens* Stal. (Hemiptera: Delphacidae) (Baehaki et al., 2017). BPH attacks rice in all growth phases, destroying it by sucking plant cell fluids and acting as vectors for viral diseases. Severe attacks can cause puso (hopperburn) and crop failures (Sianipar et al., 2017). Effective control of BPH is necessary because it is a pest that is easily resistant to synthetic insecticides (Ali, 2018), exhibits high feeding activity, has a rapid life cycle, and can fly long distances during its adult phase (Listihani et al., 2022). Synthetic insecticides are widely used by farmers today (Nath et al., 2024). The negative impacts of synthetic insecticides include farmers' dependence on continuous use, environmental pollution, the killing of natural enemies, the development of pest resistance and resurgence, and the accumulation of soil residues and residues in agricultural commodities (Singkoh and Katili, 2019).

The implementation of integrated pest management (IPM) is the right solution for addressing pest problems while also preserving the environment (Al Shalchi and Al-Jorany, 2018; Munar et al., 2023). IPM actions can effectively control BPH pests (Cai et al., 2023). One pest control technique that is compatible with other control techniques is the use of botanical insecticides. The advantages of botanical insecticides are low residues for plants and soil, easy decomposition, and safety for non-target organisms (Sutriadi et al., 2020). Additionally, the level of pest resistance is low, and the residues in the products are minimal.

The use of pesticides by growers, which is considered practical for controlling pests and plant diseases, hurts the environment. In field applications, the use of synthetic pesticides is not always practical; only about 20% are on target, while the remaining 80% falls to the ground and accumulates in the soil (Othman and Kakey, 2021; Zarkani and Prijono, 2009). Pesticide residues will be able to poison non-target organisms that are beneficial to humans (for example natural enemies of pests, as well as other animals that support the function of nature conservation), which will cause new pest strains that are resistant to pesticides, causing pest resurgence (increasing pest populations that cause pesticides to occur) explosion of secondary pests and potential pests (Adriyani, 2006).

The utilization of plants as botanical insecticides is an alternative solution to reduce the use of synthetic pesticides (Palla et al., 2020). Bioinsecticides typically contain bioactive compounds, including cyanides, terpenoids, phenylpropanes, alkaloids, acetogenins, essential oils, flavonoids, steroids, and tannins (Miranti and Fatiqin, 2018). The Zingiberaceae family, which is reported to have insecticidal properties, includes the ginger plant (*Zingiber officinale* R.) (Madreseh-Ghahfarokhi et al., 2018). (Liu et al., 2022) reported that there are eight compounds in *Z. officinale* R. including phenolic acids, flavonoids, alkaloids, quinones, terpenoids, lignin, coumarins, and tannins. The highest content was phenolic acid, followed by flavonoids at 41.5% and 27.1%, respectively. According to spectral analysis, it was known that the most abundant phenolic acid was 10-Paradol at 7.17%, and the most abundant flavonoid was quercetin-3-O-rutinoside at 12.88%. The bioactive compounds in *Z. officinale* R. can be used as insecticides to control aphids.

Anwar et al. (2018) reported that the use of *Z. officinale* R. as a botanical insecticide significantly reduced the *Aedes aegypti* population at concentrations of 0.5%, 1.0%, 1.5%, 2.0% and 2.5% with successive mortality of 32.5%, 33.8%, 51.3%, 58.8% and 65.0%. *Z. officinale* R. has been reported to have insecticidal activity, namely inhibiting *Drosophila melanogaster* mating, inhibiting oviposition because it is repellent to the adult whitefly *Bemisia argentifolii* (Zhang et al., 2004), and causing mortality of *Diaphania hyalinata* larvae (Moreira da Silva et al., 2020). *Z. officinale* R. which contains flavonoid compounds, was also reported to be effective in controlling the leafcutter parasite population of *Pteromalus venustus* on alfalfa plants and to have insecticidal activity against *Tribolium castaneum* (Ahmad et al., 2019; Ong et al., 2020). Fumigation at sublethal concentrations, furthermore, significantly reduced the oviposition potential of adults and inhibited the development of larvae to pupae and pupae to adults, with 40 and 80% of the 24-hour LC50 of *Z. officinale* R. essential oil (Chaubey, 2011). Preliminary test results showed that the application of the *Z. officinale* R. formulation on BPH nymphs suppressed the development of BPH nymphs at concentrations of 0.25%, 0.5%, 0.75%, and 1%, with consecutive nymphal mortality rates of 20%, 51.2%, 55.6%, and 60%, respectively. Nymph mortality occurred 2–4 days after application. This study aimed to determine the activity and capability of *Z. officinale* R. botanical pesticide formulation and its economic potential for controlling BPH.

Methodology

Study Site

The study was conducted at the Insect Bioecology Laboratory, Faculty of Agriculture, Andalas University, from September 2022 to March 2023.

Research Design

The study employed a completely randomized design (CRD) with seven treatments and four replications. *Z. officinale* R. was used at concentrations of 0.25%, 0.49%, 0.70%, 0.98%, and 1.38%, along with synthetic pesticides and a control—calculation of concentration based on preliminary tests.

Nilaparvata lugens **Stal (BPH)**

Twenty pairs of BPH adults were collected from rice fields at the Pauh sub-district, Padang city, and transferred into jars containing rice grains of the IR42 variety. BPH adults were released after 3 days of infestation so that the stadia obtained were uniform. Rice seedlings were reared until the BPHs developed into third-generation second-instar nymphs.

Preparation of raw materials for botanical insecticides

Processing is performed by cutting the rhizome of *Z. officinale* R. into small pieces to facilitate the fast drying process. Drying was carried out in a rattan tray with a diameter of 60 cm, which was first covered with paper. This drying process was performed for ± 2 weeks until the rhizomes became completely dry (Jebur and Almaaeny, 2018). After *Z. officinale* R. was dried, the material was refined using a blender. The results of the blender from *Z. officinale* R. were sifted using a 0.5 mm sieve to obtain *Z. officinale* R. powder.

***Extraction of Z. officinale* Roscoe**

Z. officinale R. was extracted using the maceration digestion method (Putri, 2014). *Z. officinale* R. powder (50 g) was weighed and placed in a 1000 mL Erlenmeyer. Next, 250 mL of 96% ethanol was added at a ratio of 1:5. The mixture was heated and stirred on a hot plate for 120 min at 40°C. It was left for 24 h so that the red ginger powder could settle. The samples were filtered using Whatman filter paper No. 41. Subsequently, they were evaporated using a rotary evaporator at a temperature of 45°C and a pressure of 227 barmm Hg. The solution obtained from the evaporation process was reused to re-soak the plant extract dregs up to three immersions. The extract obtained was then stored in a refrigerator at 4°C until used for testing.

Formulation of Z. officinale Roscoe

The extract obtained from *Z. officinale* R. plant material is used as a basic ingredient in making an emulsifiable concentrate (EC) with a 20% fraction. The 20 EC formulation was prepared by mixing 20% active extract ingredients, 10% Tween 80 as an emulsifier, and 70% methanol as a carrier (by volume), then stirring until all the ingredients were thoroughly mixed.

Formulation testing against BPH

Ten rice stalks, aged 14 days after the seedlings were planted in plastic cups filled with soil media. Ten instar II BPH nymphs were infested into the rice seedlings and then covered with tubular plastic mica. The top was covered with fine gauze so that the BPH would not come off. The pesticide formulation was applied evenly to the BPHs according to the specified concentration. The BPH count was maintained, and the nymph mortality was counted until 7 days after application of *Z. officinale* R. The BPH were maintained until the adult stage was formed, and the number of adults formed, as well as the number of adults that were not disabled, was recorded.

$$\text{Nymph mortality} = \frac{\textit{number of living nympfs}}{\textit{number of nympfs teste}} \times 100\%$$

$$\text{Adults formed} = \frac{\textit{number of living adults}}{\textit{number of nympfs teste}} \times 100\%$$

Data analysis

The data were processed using variance, and if they were significantly different, they were further tested using LSD at the 5% level.

Results

The results showed that the application of *Z. officinale* R. formulation increased the mortality of BPH nymphs. The highest BPH nymph mortality was observed at a concentration of 1.38%, with a mortality rate of 80%. Concentrations of 0.70% and 0.90% had the same ability to increase the mortality of BPH nymphs by 60% and 65%, respectively. The lowest mortality was observed in the *Z. officinale* R. formulation treatment at a concentration of 0.25%, with a nymph mortality of 35%. These results indicate that the increase in the concentration of the *Z. officinale* R. formulation is proportional to the increase in the mortality of BPH nymphs; the higher the concentration, the higher the mortality of BPH nymphs (Table 1).

Table 1. Mortality of BPH nymphs by spraying the botanical insecticide formulation *Z. officinale* Roscoe

Treatments	Percentage nymph mortality of BPH (%) ± SD			
Synthetic insecticide	90.00	±	0.82	a
1.38%	80.00	±	0.58	b
0.98%	65.00	±	0.82	c
0.70%	60.00	±	0.82	c
0.49%	50.00	±	0.82	d
0.25%	35.00	±	0.58	e
Control	0	±	0	f

Note: numbers followed by the same letters are not significantly different based on the LSD test level of 5%

The formulation of *Z. officinale* R. in the form of EC suppresses the development of BPH. However, it has a low ability to increase nymph mortality when compared to treatments using synthetic insecticides. The daily mortality of nymphs treated with *Z. officinale* R. formulations occurred on days 1 – 4. Concentrations of 1.38%, 0.25%, and 0.49% took 3 days to kill BPH nymphs, which had the same ability as treatments using synthetic insecticides. Concentrations of 0.70% and 0.98% took 4 days to kill BPH nymphs, which was longer than the other treatments (Figure 1).

The results showed that the application of *Z. officinale* R. formulation reduced the number of BPH adults formed. The

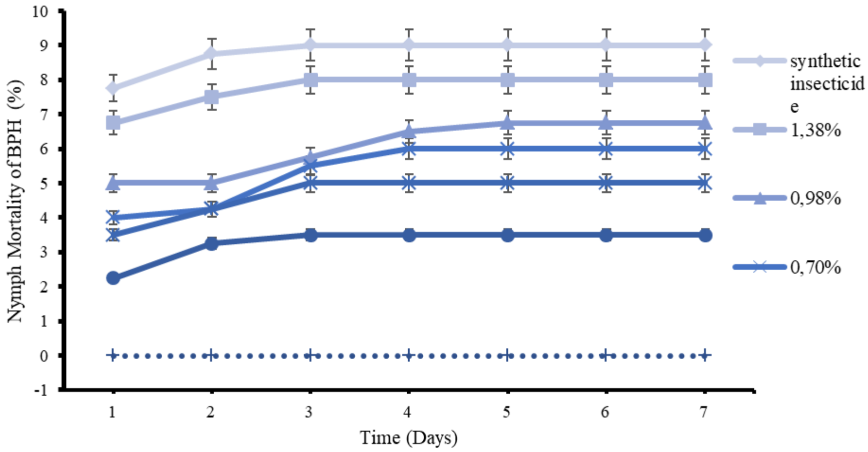

Fig. 1. Daily mortality of BPH nymphs by spraying the botanical insecticide formulation *Z. officinale* Roscoe

number of adults formed affects the number of offspring in the next generation. If there are many adults, the number of offspring may also increase, and vice versa. Application of the *Z. officinale* R. formulation by spraying reduced adults formation to 15% of the 10 tested nymphs. The number of adults formed by the application of *Z. officinale* R. formulations had the same ability as synthetic insecticides. A concentration of 0.25% had a lower ability to reduce the number of adults formed, which was equal to 65%.

The formulation of the botanical pesticide *Z. officinale* R. resulted in the death of BPH nymphs. Affected BPH nymphs have a characteristic coloration of the thorax, while the abdomen has a more discolored, soft body. Infected BPH nymphs have initial symptoms, namely slowing of the movement of the nymphs; over time, the body becomes stiff, and the BPH nymphs fall to the ground and eventually die (Figure 2).

The administration of various concentrations of *Z. officinale* R. affected the mortality rate and number of BPH adults formed. The most influential concentration in providing mortality and feeding inhibition in BPH nymphs was 1.38%, with a mortality rate of 80% (Table 1), and the percentage of imagoes formed was 15% (Table 2). *Z. officinale* R. contains active compounds that have the potential to be used as botanical insecticides (Miranti and Fatiqin, 2018).

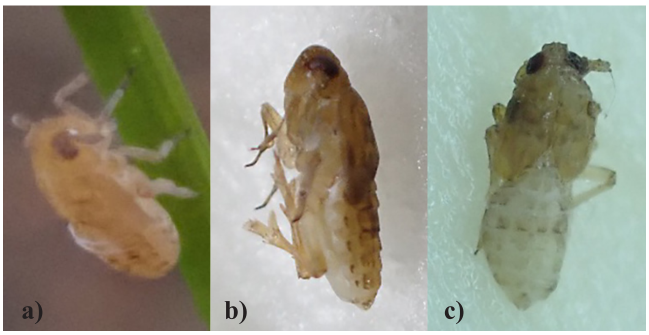

Fig. 2. (a) normal BPH nymphs treated as a control (b) BPH nymphs that died because of the botanical pesticide formulation *Z. officinale* Roscoe and (c) BPH nymphs that died because of synthetic insecticides

According to Simmonds (2003), flavonoid compounds can influence appetite and egg-laying behavior. (Ateyyat et al., 2012) reported that flavonoid compounds could kill aphid nymphs. Increasing the concentration of flavonoids increases the mortality of nymphs and has less impact on the natural enemy Aphelinus mali than the effect caused by the imidacloprid insecticide (Abbas et al., 2020). Saponins exhibit apparent insecticidal activity, causing increased mortality, reduced food intake, decreased insect weight, inhibited development/growth, inhibited molting, and decreased reproduction. According to Majid et al (2011) Moreover, emit volatile mixtures to attract natural enemies of insect pests.

Research from Liu et al. (2022) showed that the content of phenolic acid in *Z. officinale* R. was the highest, reaching 41.5%, followed by flavonoids (27.1%) and alkaloids (11.9%) (Liu et al., 2022). Phenolic acids are oxyhydryl-containing benzene-ring compounds with a unique aromatic

Table 2. The percentage of BPH adults was formed by spraying the botanical insecticide *Z. officinale* Roscoe

Treatments	Percentage adults formed (%) ± SD			
Control	100.00	±	0	a
0.25%	65.00	±	0.58	b
0.49%	50.00	±	0.82	c
0.70%	40.00	±	0.82	d
0.98%	32.50	±	0.50	d
1.38%	15.00	±	0.58	e
Synthetic insecticide	10.00	±	0.82	e

Note: numbers followed by the same letters are not significantly different based on the LSD test level of 5%

odor. Several studies have demonstrated that phenolic acids exhibit an insecticidal effect; for example, ferulic acid and coumaric acid can influence ovipositional selection in *Pieris rapae* (Walker et al., 2014). Tannic acid can extend the growth period of aphids and reduce daily fecundity (Chrzanowski et al., 2012), and salicin significantly reduces feeding function and gypsy moth survival rate. In addition, *Z. officinale* R. inhibits the growth of nymphal aphids, causing them to grow slowly and increasing their mortality. *Z. officinale* R. extract at a concentration of 20% can cause 92 the death of *Leptocorisa oratorius* (Yuandita, 2018).

Z. officinale R contains active compounds that inhibit the growth of nymph aphids, causing mass death. According to the flea digestive enzyme test, the activities of protease, lipase, and α-amylase were inhibited. Similarly, research by Chen et al. (2020) found that carvacrol can inhibit digestive enzyme activity in *Lymantria dispar. Z. officinale* R. may also contain compounds effective at inhibiting the digestive enzymes of nymph aphids. *Z. officinale* R can also inhibit the growth and development of sorghum aphids by inhibiting digestive enzymes and affecting protective enzymes and detoxification enzymes, which can cause the death of aphids. (Miladi et al., 2019) reported that Pergularia tomentosa extract significantly increased the death of *Locusta migratoria* nymphs, and (Xin et al., 2019) reported that sulfoxaflor affected the development and increased mortality of *Sitobion avenae* and *Rhopalosiphum rice lineages*.

The mechanism by which active compounds contained in red ginger enter the cell involves reacting with the cell membrane as a contact poison, damaging the cell membrane, disrupting its permeability, and causing lysis (Macwan et al., 2016). Ohsawa (2000) said that cell membranes, composed of lipids and proteins, are very susceptible to chemicals that can result in a decrease in the surface tension of the plasma membrane. Damage to the plasma membrane disrupts the transport of nutrients (compounds and ions) through the cell membrane, resulting in a deficiency of essential nutrients needed for growth. In addition to causing the release of the material in the cells and disrupting the process of transporting nutrients by the cells, damage to the cytoplasmic membrane causes other compounds found in red ginger to penetrate more freely into the bodies of the larvae.

A decrease in the activity of the digestive glands affects the chemical digestion process in the digestive tract, damaging the epithelial cells that produce digestive enzymes and damaging the regenerative cells that renew dead or damaged epithelial cells. The presence of the active compound zingiberen in the red ginger rhizome filtrate stimulates barrier receptors, which in turn send anti-feeding signals to the insect nerve center by inhibiting or disrupting impulse bursts in the nervous system. As a result, they cannot detect the presence of food around them, making it difficult for insects to perform feeding activities (Hermawan et al., 2010). Botanical pesticides can cause damage to the digestive tract and obstruct the olfactory organs in *S. litura*, thereby preventing the detection of food and reducing the feeding activity of *S. litura* (Tesari et al., 2024).

This is because reduced activity and a low level of eating insects cause them to become weak and die slowly (Strong and Brown, 1987). Saponin compounds in red ginger rhizomes exhibit insecticidal activity, which can lead to increased mortality, reduced food intake, inhibited development and growth, and disrupted molting and reproduction in insects.

Kaempferol also works physiologically as a digestive poison by causing damage to the digestive tract in the body of larvae, resulting in a decrease in the activity of the digestive glands. A decrease in the activity of the digestive glands affects the chemical digestion process in the digestive tract due to damage to epithelial cells that produce digestive enzymes and damage to regenerative cells that renew dead or damaged epithelial cells (Anwar et al., 2018). The presence of the active compound zingiberne in red ginger filtrate was also reported by to stimulate barrier receptors which will then send an “anti-feeding signal” to the insect’s nervous center by inhibiting or disrupting impulse spikes in the nervous system, so that they cannot smell (recognize information taste) so they cannot recognize the presence of food. As a result, he cannot eat properly around him (Hermawan et al., 2010).

Conculsion

Treatment with a concentration of 1.38% was the most effective in killing *Nilaparvata lugens* Stal BPH nymphs by 80.00%. Application of *Z. officinale* R. formulation affected the daily mortality of BPH nymphs. On average, BPH nymphs died in rice 1- 4 days after application. *Z. officinale* R. formulation affected the number of BPH adults formed. The number of adults formed was 15% at a concentration of 1.38%.

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