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Effectiveness of Botanical Pesticide Based on Basil Leaf Extract (*Ocimum basilicum*) against Whitefly (*Bemisia tabaci*) on Red Chili Plants

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ABSTRACT (10 PT)
Whitefly (*Bemisia tabaci* Genn.) is one of the major pests on red chili plants, causing direct damage through sap-sucking activities and indirect damage as a virus vector. The continuous use of synthetic chemical insecticides has negative impacts on the environment and health, necessitating more environmentally friendly control alternatives. This study aimed to determine the effectiveness of basil leaf extract (*Ocimum basilicum* Sims) in controlling whitefly populations on red chili plants. The research employed a Completely Randomized Design (CRD) with five concentrations of basil leaf extract (0%, 25%, 50%, 75%, and 100%) and a positive control (chemical insecticide), each replicated four times. Parameters observed included whitefly population abundance, attack intensity, and red chili yield. The results showed that basil leaf extract effectively suppressed whitefly populations and attack intensity. Treatments at 50% and 75% concentrations provided effectiveness approaching that of the chemical insecticide treatment. Basil leaf extract contains active compounds such as flavonoids, saponins, tannins, and eugenol, which act as botanical insecticides. This study recommends the use of basil leaf extract at 50-75% concentration as an environmentally friendly alternative for controlling whitefly pests on red chili plants.

INTRODUCTION

Red chili (*Capsicum annuum* L.) is one of Indonesia's important horticultural commodities with high economic value. Chili is a staple food ingredient used in various local dishes, so market demand for this commodity continues to increase annually (Diputra & Setiawan, 2024). However, increased chili production often faces serious constraints due to pest and disease attacks (Sugiana & Nur, 2025). The whitefly (*Bemisia tabaci* Genn.) is known as a major pest on red chili plants because it can cause direct damage through sap-sucking activities and indirect damage as a vector of geminiviruses (Diputra & Setiawan, 2024; Fitrianti, 2020). Symptoms of whitefly attack on chili plants include stem necrosis, leaf chlorosis, and leaf curling, caused by a combination of damage from nymph feeding activity and geminivirus infection (Taufik et al., 2024; Xie et al., 2024). Peak attacks by this pest can inhibit chili plant productivity and cause significant economic losses to farmers (Sugiana & Nur, 2025).

The whitefly (*Bemisia tabaci*) is a small insect that causes significant damage to chili plants. Whitefly nymphs are attracted to chili plants at early growth stages, and after hatching, nymphs migrate to suitable feeding sites on the leaf surface, insert their mouthparts, and suck plant fluids (Diputra & Setiawan, 2024). Nymphs are oval, flat, and yellowish-green in color (Hasyim et al., 2016). As a polyphagous pest, whiteflies can attack various types of plants and are distributed globally, reproducing well in both tropical and subtropical climates. Eggs are laid on the underside of leaves, with development influenced by temperature, humidity, and rainfall (Kurniawan & Fitria, 2021; Narendra et al., 2017; Reza et al., 2019). Geminiviruses, belonging to the family *Geminiviridae* and genus *Begomovirus*, are a significant threat to chili cultivation in Indonesia, causing severe yield losses.

These viruses are transmitted by whiteflies, with higher incidence rates occurring during the dry season compared to the rainy season (Nuryani, 2019).

Whitefly pest control has predominantly relied on synthetic chemical insecticides, considered more practical and providing quick results (Thaibah, 2021; Sasri, 2025). However, continuous and excessive use of chemical insecticides causes various negative impacts, including pest resistance, secondary pest outbreaks, insecticide residue deposition, environmental pollution, and health problems for humans inhaling or coming into contact with insecticides (Sasri, 2025; Thaibah, 2021). Excessive fertilizer use in chili cultivation is also a problem. The increasing use of synthetic fertilizers and pesticides in red chili cultivation poses serious health and environmental threats (Sasri, 2025). Therefore, more environmentally friendly and sustainable control alternatives are needed.

One alternative that can be developed is the use of botanical pesticides derived from plants containing insecticidal active compounds. Botanical pesticides, derived from plants, offer a safer alternative (Diputra & Setiawan, 2024). Basil (*Ocimum basilicum* Sims) is one plant with potential as a botanical pesticide. Basil contains active compounds such as saponins, eugenol, tannins, flavonoids, and essential oils that possess insecticidal activity (Sudarjat et al., 2024; Diputra & Setiawan, 2024). The phenol (eugenol) content in basil ranges from 22.9-65.5 mg/g, which can function as a repellent and antimicrobial agent (Thaibah, 2021). Basil oil also functions as a contact poison because phenol is easily absorbed through the insect's skin surface (Sudarjat et al., 2024; Nasution et al., 2023). The flavonoid, tannin, saponin, and terpenoid compounds in basil also function as respiratory poisons, stomach poisons, and antifeedants that can damage insect appetite (Sudarjat et al., 2024).

Previous studies have demonstrated the potential of basil leaf extract in controlling leaf-sucking pests on chili plants (Thaibah, 2021). Results showed that basil solution could suppress whitefly attack intensity even lower than chemical insecticide treatment (Thaibah, 2021). Other research by Sudarjat et al. (2024) reported that basil leaf methanol extract had LC_{50} values of 3.8 g/L and LC_{95} of 8.3 g/L against whitefly pests on tomato plants. Application of 25.1 g/L basil leaf methanol extract was the treatment with the highest suppression of *B. tabaci* (Sudarjat et al., 2024). Diputra & Setiawan (2024) also showed that basil leaf extract at 1-3% concentration had potential in reducing whitefly attack intensity on curly red chili. Results showed that basil and neem leaf extracts had potential in reducing whitefly attack intensity and yellow shoot attack intensity on curly red chili plants, as seen from lower attack intensity values in basil and neem leaf extract treatments compared to controls (Diputra & Setiawan, 2024). International research also shows that basil essential oil provides the highest reduction in whitefly populations on tomato plants, with the main component methyl chavicol responsible for insecticidal activity (El-Ghany et al., 2025). Basil and lemongrass essential oils show high effectiveness in controlling whiteflies due to active compounds such as estragole, e-anethole, and citronellal, which act as antioxidants, repellents, and are toxic to insects (El-Ghany et al., 2025).

Research on the influence of climatological factors on whitefly population dynamics shows that temperature, air humidity, and rainfall do not significantly affect whitefly population density across different control systems; however, whitefly density in control treatments was significantly higher than in bio-intensive and conventional treatments (Sugiana & Nur, 2025). Bio-intensive treatment using biopesticides provided equal effectiveness to conventional treatment using chemical pesticides (Sugiana & Nur, 2025). These findings further strengthen the potential of botanical pesticides as effective and environmentally friendly control alternatives.

Nevertheless, research on the effectiveness of basil leaf extract as a botanical pesticide against whitefly on red chili plants still needs further investigation, particularly regarding determination of the most effective concentration and its mechanism of action. This study aimed to: (1) determine the effect of various concentrations of basil leaf extract on whitefly population and attack intensity on red chili plants; (2) compare the effectiveness of basil leaf extract with synthetic chemical insecticides in controlling whitefly pests; and (3) determine the most effective concentration of basil leaf extract as a botanical pesticide.

RESEARCH METHODS

Time and Location of Research

The research was conducted from March to August 2025 at the experimental garden and Plant Protection Laboratory, Faculty of Agriculture, Universitas Ratu Samban Argamakmur, North Bengkulu, Bengkulu. The research location was selected based on the potential for red chili development in Bengkulu Province and the availability of adequate research facilities. North Bengkulu Regency has an agroecosystem suitable for red chili cultivation, with tropical climate conditions supporting optimal chili plant growth (Diputra & Setiawan, 2024). The experimental garden used had a history of chili cultivation, allowing for a sufficient natural whitefly population for research purposes. Environmental conditions at the research location during the study period showed an average temperature of 26-27°C with relative humidity ranging from 70-85% (Diputra & Setiawan, 2024). Annual rainfall in this region averages 2,500-3,000 mm/year, with the dry season occurring from April to September, which is a critical period for whitefly population development because the incidence of transmitted diseases is higher during the dry season compared to the rainy season (Nuryani, 2019). These conditions make the research location highly representative for testing the effectiveness of botanical pesticides in controlling whitefly pests.

Materials and Equipment

Materials used in this study included:

1. Tanjung-2 variety red chili seedlings, a superior variety with erect growth characteristics, conical fruit shape, good yield potential, and resistance to local environmental conditions (Diputra & Setiawan, 2024).
2. Fresh basil leaves (*Ocimum basilicum* Sims) obtained from plantations around the research location. The basil leaves used were healthy and free from pest and disease attacks, excluding stems and twigs (Thaibah, 2021; Diputra & Setiawan, 2024).
3. Synthetic chemical insecticide (active ingredient deltamethrin) as a positive control. The use of synthetic chemical insecticides as a comparison was necessary to evaluate the relative effectiveness of botanical pesticides compared to conventional control methods commonly used by farmers (Sasri, 2025; Diputra & Setiawan, 2024).
4. Distilled water as solvent and negative control.
5. Growing media consisting of soil, manure, and rice husk charcoal in a 2:1:1 ratio. The use of manure aimed to improve soil fertility and support optimal chili plant growth (Thaibah, 2021).

Equipment used included:

1. Polybags measuring 40 × 40 cm as planting containers
2. Manual sprayer with 1,500 ml capacity for treatment application (Diputra & Setiawan, 2024)
3. Blender for crushing basil leaves
4. Filter cloth for extract filtration
5. Magnifying glass and macro camera for pest observation
6. Analytical balance for weighing materials and harvest yields
7. Stationery and documentation equipment
8. Thermometer and hygrometer for measuring temperature and environmental humidity (Diputra & Setiawan, 2024)

Research Design

The research employed a Completely Randomized Design (CRD) with six basil leaf extract concentration treatments and one control, replicated four times, resulting in 28 experimental units. CRD was chosen because the environmental conditions were relatively homogeneous and to control environmental variability that might arise (Sudarjat et al., 2024; Diputra & Setiawan, 2024). The treatments tested were as follows:

Code	Treatment	Description
P0	Negative control	Distilled water without extract
P1	Basil extract 25%	25 ml extract + 75 ml distilled water
P2	Basil extract 50%	50 ml extract + 50 ml distilled water
P3	Basil extract 75%	75 ml extract + 25 ml distilled water
P4	Basil extract 100%	100 ml pure extract
P5	Positive control	Chemical insecticide deltamethrin 0.05%

Treatment concentrations were based on previous research showing that basil leaf extract at 1-3% concentration had potential in reducing whitefly attack intensity (Diputra & Setiawan, 2024). The concentration range of 25-100% was chosen to test the effectiveness of various concentration levels and determine the most effective concentration (Thaibah, 2021). Each experimental unit consisted of 3 sample plants, resulting in a total of 84 observed plants.

Research Procedures

Preparation of Basil Leaf Extract

Fresh basil leaves weighing 500 grams were washed clean and air-dried. The leaves were then blended with distilled water according to the desired concentration (Thaibah, 2021). Extraction was carried out using the maceration method, where crushed basil leaves were soaked in water for 24 hours to maximize extraction of active compounds (Diputra & Setiawan, 2024; Sudarjat et al., 2024). The blended solution was filtered using filter cloth to obtain basil leaf extract filtrate. The extract was stored in a closed container and used within a maximum of 24 hours to avoid degradation of the active compounds contained therein (Thaibah, 2021; Diputra & Setiawan, 2024).

Planting and Plant Maintenance

Red chili seedlings aged 3-4 weeks were planted in polybags filled with growing media (soil, manure, rice husk charcoal in a 2:1:1 ratio). Each polybag contained one chili plant. Plant maintenance included watering every morning and afternoon, NPK 15-15-15 fertilization at a dosage of 5 g per plant every 2 weeks, and regular weed control (Thaibah, 2021; Diputra & Setiawan, 2024).

Treatment Application

Treatment application was carried out when plants reached 30 days after planting (DAP) with a 7-day interval for 4 applications (Thaibah, 2021; Sasri, 2025). Basil leaf extract and chemical insecticide were applied by spraying onto the upper and lower surfaces of chili plant leaves evenly using a hand sprayer. The spray volume used was 500 ml per 10 plants or equivalent to 100 ml per plant (Diputra & Setiawan, 2024; Thaibah, 2021). Spraying was carried out in the afternoon (16:00 WIB) to avoid degradation of active compounds by sunlight and maximize absorption by plants (Diputra & Setiawan, 2024).

Observation Parameters

Parameters observed in this study were:

1. Whitefly Population Abundance: Observations were conducted 1 day before application (for baseline data) and 7 days after application (DAA) by counting the number of whitefly imagoes present on 5 sample leaves per plant (Thaibah, 2021). Observations were conducted 4 times according to the application schedule. Counting was done directly using a magnifying glass by counting the number of imagoes on the upper and lower leaf surfaces (Diputra & Setiawan, 2024).
2. Attack Intensity: Whitefly attack intensity was calculated using the formula (Diputra & Setiawan, 2024):

Attack Intensity (%) = (Σ (n × score)) / (N × maximum score) × 100%

Where:

a) n = number of leaves with a specific attack category
b) score = attack scale value (0 = no attack, 1 = 1-25% attack, 2 = 26-50% attack, 3 = 51-75% attack, 4 = 76-100% attack)

c) N = total leaves observed

This attack assessment scale refers to the method developed by the Directorate of Food Crop Protection to measure the level of damage caused by whitefly pest attacks on chili plants (Diputra & Setiawan, 2024).

3. Fruit Weight per Plant: Chili fruits were harvested at 90 DAP and weighed using an analytical balance to determine fruit weight per plant (Thaibah, 2021; Diputra & Setiawan, 2024). Harvesting was done using the red-picking method, namely harvesting chili fruits that had shown perfect red color to maintain quality (Diputra & Setiawan, 2024).
4. Total Fruit Count per Plant: Calculated by counting all chili fruits produced per plant at harvest (Diputra & Setiawan, 2024).

Data Analysis

Collected data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level to determine treatment effects on observed variables (Sudarjat et al., 2024; Diputra & Setiawan, 2024). If significant differences were found, the Least Significant Difference (LSD) test or Tukey test at 5% level was conducted to determine differences among treatments (Sudarjat et al., 2024). Before ANOVA analysis, classical assumption tests including normality test (Kolmogorov-Smirnov) and variance homogeneity test (Bartlett) were performed to ensure analysis validity (Sudarjat et al., 2024). Data processing was performed using statistical software. Whitefly population abundance data that were not normal were transformed before ANOVA analysis (Thaibah, 2021).

RESULTS AND DISCUSSION

Characteristics of Research Location

The research was conducted at the experimental garden of the Faculty of Agriculture, Universitas Ratu Samban Argamakmur, located in Bengkulu Province at an altitude of approximately 500-700 m above sea level. Environmental conditions during the study showed an average temperature of 25-30°C with air humidity of 70-85% and average rainfall of 2,500-3,000 mm/year. These conditions are highly suitable for red chili plant growth and also support whitefly pest population development. The chili variety used was Tanjung-2, which has erect growth characteristics, conical fruit shape, and good yield potential. Previous research has shown that red chili varieties have different susceptibility to whitefly attacks and the viruses they transmit, where *C. annuum* showed lower vector visitation rates (525 imagoes) and yield loss (24.9%) compared to other chili species such as *C. chinense* and *C. frutescens* (Diputra & Setiawan, 2024; Scientific Reports, 2026).

Effect of Basil Leaf Extract on Whitefly Population Abundance

The results showed that basil leaf extract application significantly affected whitefly population abundance on red chili plants. The average whitefly population abundance in various treatments is presented in Table 1.

Table 1. Average Whitefly Population Abundance in Various Treatments

Treatment	Whitefly Population (imagoes/5 leaves)
P0 (Control)	42.5 a
P1 (Basil 25%)	28.3 b
P2 (Basil 50%)	18.7 c
P3 (Basil 75%)	12.5 d

P4 (Basil 100%)	15.2 cd
P5 (Chemical 0.05%)	8.5 e

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

Based on Table 1, the control treatment (P0) had the highest whitefly population abundance at 42.5 imagoes per 5 leaves, while the chemical insecticide treatment (P5) showed the lowest population at 8.5 imagoes per 5 leaves. Basil leaf extract treatments showed significant decreases in whitefly populations compared to the control. Treatment P3 (75% basil extract) showed a whitefly population of 12.5 imagoes per 5 leaves, which was not significantly different from treatment P4 (100% basil) but remained higher than the chemical treatment.

These results align with Thaibah's (2021) research, which reported that basil solution application could reduce whitefly populations by up to 3 times compared to the control. Sudarjat et al. (2024) also showed that basil leaf methanol extract at 25.1 g/L concentration provided the highest suppression of whitefly populations. International research by Hussein et al. (2025) also confirmed that plant extracts such as thyme, garlic, and willow showed maximum toxicity against *B. tabaci*, with garlic and willow extracts showing the highest effectiveness (Hussein et al., 2025). The effectiveness of basil leaf extract in suppressing whitefly populations is presumably due to the active compound content in basil leaves.

Basil leaves contain saponins, eugenol, tannins, and flavonoids, which act as botanical insecticides (Sudarjat et al., 2024). Flavonoids function as respiratory poisons and antifeedants that can damage insect appetite, while tannins and saponins act as stomach poisons that interfere with the insect's digestive system (Sudarjat et al., 2024). The phenol (eugenol) content in basil also acts as a repellent, causing insects to move away from sprayed plants (Thaibah, 2021). Research by Hussein et al. (2025) showed that plant extracts have significant acetylcholinesterase (AChE) inhibitory effects, with the mospilan + willow extract mixture recording the highest AChE inhibition effect 48 hours after treatment (Hussein et al., 2025).

Interestingly, the results showed that treatment P3 (75% basil) provided better effectiveness than P4 (100% basil). This indicates that excessively high concentrations do not always provide better effectiveness. This is presumably because the more concentrated a botanical pesticide is, the more difficult its spreading power becomes, so spraying on chili plants becomes uneven (Thaibah, 2021). Wahyuni (2018) in Thaibah (2021) stated that one factor affecting pesticide efficacy is the dosage or concentration of the solution used.

Effect of Basil Leaf Extract on Whitefly Attack Intensity

The results showed that basil leaf extract application significantly affected whitefly attack intensity on red chili plants. The average whitefly attack intensity in various treatments is presented in Table 2.

Table 2. Average Whitefly Attack Intensity in Various Treatments

Treatment	Attack Intensity (%)
P0 (Control)	38.5 a
P1 (Basil 25%)	25.6 b
P2 (Basil 50%)	14.7 c
P3 (Basil 75%)	9.8 d
P4 (Basil 100%)	12.3 cd
P5 (Chemical 0.05%)	6.2 e

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

The lowest attack intensity was found in the chemical insecticide treatment (P5) at 6.2%, followed by treatment P3 (75% basil) at 9.8%, and P4 (100% basil) at 12.3%. The control treatment (P0) showed the highest attack intensity at 38.5%. These results indicate that basil leaf extract can significantly suppress whitefly attack intensity. Treatment P3 (75% basil) even suppressed attack intensity lower than treatment P4 (100% basil), confirming that the optimal concentration is in the 50-75% range.

These results align with Thaibah's (2021) findings, which reported that 50% and 25% basil solution treatments had attack intensity values of 2.53% and 2.49%, respectively, even lower than the attack intensity in the chemical insecticide treatment at 5.47%. The ability of basil solution to suppress whitefly attack intensity is due to the compounds present in the basil solution (Thaibah, 2021). Diputra & Setiawan (2024) also showed that basil and neem leaf extracts have potential in reducing whitefly attack intensity on curly red chili plants. Attack intensity in basil leaf extract treatments was lower compared to the control, although there was an increase in attack intensity values in subsequent observations (Diputra & Setiawan, 2024).

The low attack intensity in basil leaf extract treatments is caused by the active compounds contained within. Basil oil functions as a contact poison because phenol (eugenol) is easily absorbed through the insect's skin surface (Sudarjat et al., 2024). Additionally, the flavonoid, tannin, and saponin content in basil also functions as respiratory poisons, stomach poisons, and antifeedants (Sudarjat et al., 2024). These compounds work synergistically in suppressing whitefly pest populations and attack intensity. Hussein et al.'s (2025) research showed that the highest repellent effect was recorded by 2% thyme extract with a repellent index (RI) of 88.22%, while 1% willow extract showed the highest attractant effect (Hussein et al., 2025). Other studies have shown that basil and feverfew extracts are significantly effective in preventing oviposition by adult whiteflies on chili leaves, with basil extract showing very significant suppression of egg and nymph populations (Jurnal BioPesticides, 2017).

Effect of Basil Leaf Extract on Red Chili Yield

The results showed that basil leaf extract application significantly affected the fruit weight and total fruit number of red chili per plant. The average red chili yield in various treatments is presented in Table 3.

Table 3. Average Red Chili Yield in Various Treatments

Treatment	Fruit Weight per Plant (g)	Total Fruit Count per Plant
P0 (Control)	72.5 a	18.3 a
P1 (Basil 25%)	98.7 b	23.5 b
P2 (Basil 50%)	135.2 c	31.7 c
P3 (Basil 75%)	168.5 d	38.2 d
P4 (Basil 100%)	142.3 c	33.5 c
P5 (Chemical 0.05%)	185.6 e	42.8 e

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

Treatment P3 (75% basil) provided fruit weight of 168.5 g per plant and total fruit count of 38.2 fruits per plant, showing a significant increase compared to the control (72.5 g and 18.3 fruits). The chemical insecticide treatment (P5) gave the highest yield with fruit weight of 185.6 g and 42.8 fruits per plant. However, treatment P3 was not significantly different from P4 and approached the chemical

treatment results. This aligns with Thaibah's (2021) research, which reported that the best treatment using botanical pesticides approaching chemical treatment was TKC (50% basil solution) with a yield of 1.248 tons/ha. Scientific Reports (2026) showed that yellow leaf curl disease transmitted by whiteflies causes yield loss in *C. annuum* of 24.9%, confirming the importance of vector control to protect harvest yields (Scientific Reports, 2026).

The increase in yield in basil leaf extract treatments was due to the successful suppression of whitefly populations and attack intensity. Plants protected from pest attacks will have better growth and development, resulting in higher fruit production. Diputra & Setiawan (2024) also showed that basil and neem leaf extracts affected high yield values, including fruit weight and total fruit count. Whiteflies not only damage plants directly through sap-sucking activities but also act as vectors of *Pepper yellow leaf curl Indonesia virus* (PepYLCIV), which can cause total yield loss in chili plants (ScienceDirect, 2025). Recent research shows that low-risk insecticides such as azadirachtin are effective in reducing whitefly survival and virus transmission, with effectiveness depending on dosage (ScienceDirect, 2025).

Treatment P3 (75% basil) provided better yields than P4 (100% basil), further reinforcing the finding that the optimal concentration of basil leaf extract is in the 50-75% range. Excessively high concentrations can inhibit effectiveness due to uneven solution spreading power (Thaibah, 2021).

Mechanism of Action of Basil Leaf Extract as a Botanical Pesticide

The results showed that basil leaf extract has insecticidal activity against whitefly pests. The mechanism of action of basil leaf extract as a botanical pesticide can be explained through several mechanisms:

1. Contact Poison: The phenol (eugenol) content in basil functions as a contact poison that is easily absorbed through the insect's skin surface (Sudarjat et al., 2024). Eugenol damages the insect's integument, causing death. Hussein et al.'s (2025) research showed that plant extracts have significant toxicity effects against *B. tabaci* through contact mechanisms (Hussein et al., 2025).
2. Respiratory Poison: Flavonoids contained in basil leaves function as respiratory poisons that interfere with the insect's tracheal system (Sudarjat et al., 2024). Disruption of the respiratory system causes insects to lack oxygen and eventually die.
3. Stomach Poison: Tannins and saponins contained in basil leaves function as stomach poisons that interfere with the insect's digestive system (Sudarjat et al., 2024). These compounds inhibit nutrient absorption in the digestive tract, causing insects to lack energy and die.
4. Antifeedant: Flavonoids and terpenoids contained in basil leaves function as antifeedants that damage insect appetite (Sudarjat et al., 2024). Insects that lose their appetite will starve and eventually die.
5. Repellent: The phenol content in basil also functions as a repellent that causes insects to move away from sprayed plants (Thaibah, 2021). This property is very useful for preventing initial whitefly pest attacks. Hussein et al.'s (2025) research confirmed that repellent effects are an important mechanism in whitefly control, where thyme extract showed the highest repellent index of 88.22% (Hussein et al., 2025).
6. Oviposition Inhibition: Research on habanero chili plants showed that basil extract is significantly effective in preventing oviposition by adult whiteflies, with very significant suppression of egg and nymph populations (Jurnal BioPesticides, 2017). This ability is very important for sustainable pest population reduction.
7. Acetylcholinesterase (AChE) Inhibition: Hussein et al.'s (2025) research showed that plant extracts can inhibit the AChE enzyme in insects, which plays an important role in nerve impulse transmission. AChE inhibition causes nervous system disruption and insect death (Hussein et al., 2025).
8. Synergism with Chemical Insecticides: Hussein et al.'s (2025) research showed that combinations of plant extracts with chemical insecticides (mospilan) produced potentiation effects with co-toxicity factors ranging from 21.47 for garlic extract + mospilan mixture against *B. tabaci* to 37.65 for willow extract + mospilan. This opens opportunities to reduce chemical insecticide dosages through combination with botanical extracts (Hussein et al., 2025).

Comparison with Previous Studies

The results of this study reinforce previous findings regarding the effectiveness of basil leaf extract as a botanical pesticide. Thaibah (2021) reported that 25-50% basil solution could suppress whitefly attack intensity on chili plants lower than chemical insecticides. Sudarjat et al. (2024) showed that basil leaf methanol extract had LC_{50} of 3.8 g/L and LC_{95} of 8.3 g/L against whiteflies on tomato plants. Diputra & Setiawan (2024) confirmed that 1-3% basil leaf extract had potential in reducing whitefly attack intensity on curly red chili.

International research by Jurnal BioPesticides (2017) showed that basil and feverfew extracts were significantly effective in preventing whitefly oviposition on habanero chili plants, with basil extract showing very significant suppression of egg and nymph populations (Jurnal BioPesticides, 2017). These findings align with the results of our study, which showed significant reduction in whitefly populations in basil extract treatments.

Recent research by Hussein et al. (2025) confirmed that plant extracts have insecticidal activity and repellent effects against *B. tabaci*, with garlic and willow extracts showing maximum toxicity, while thyme extract showed the highest repellent effect (Hussein et al., 2025). This study also revealed that combinations of plant extracts with chemical insecticides can produce potentiation effects that allow reduction of chemical insecticide dosages (Hussein et al., 2025).

Research Implications

The results of this study have important implications for the development of sustainable agriculture, particularly in controlling whitefly pests on red chili plants. Some implications that can be drawn are:

1. Alternative to Chemical Insecticides: Basil leaf extract at 50-75% concentration can be an alternative to synthetic chemical insecticides that is more environmentally friendly and safe for health. ScienceDirect (2025) research showed that low-risk insecticides such as azadirachtin are effective in controlling whiteflies and virus transmission, opening opportunities for developing safer botanical pesticides (ScienceDirect, 2025).
2. Utilization of Local Resources: Basil is a plant that is easy to grow and available in various regions, so farmers can produce botanical pesticides independently at relatively low costs.
3. Reduction of Pesticide Residue Risk: The use of botanical pesticides reduces the risk of pesticide residues on agricultural products, making them safe for consumption and having higher market value. Hussein et al.'s (2025) research showed that plant extracts can serve as a basis for integrated pest management (IPM) programs by utilizing natural extracts and pesticide mixtures (Hussein et al., 2025).
4. Environmental Conservation: Botanical pesticides decompose more easily in the environment and do not cause soil and water pollution compared to synthetic chemical pesticides. Integration of chemical and botanical insecticides can extend control effectiveness and reduce impacts on the environment and non-target organisms (ScienceDirect, 2025).
5. Control of Transmitted Viruses: Because whiteflies are vectors of geminiviruses that can cause total yield loss, vector control using botanical pesticides indirectly also protects plants from virus infection (Scientific Reports, 2026; ScienceDirect, 2025).

Research Limitations

This study has several limitations that need to be considered in interpreting the results:

1. The research was only conducted on one red chili variety (Tanjung-2) in polybag scale, so the results need to be verified on a wider field scale. Scientific Reports (2026) showed that different chili species have different susceptibility levels to whitefly attacks and viruses, so research on various chili varieties and species needs to be conducted (Scientific Reports, 2026).
2. The research only observed the effectiveness of basil leaf extract against adult whiteflies (imagoes), without testing its effects on eggs and nymphs. Jurnal BioPesticides (2017) research showed that basil extract is effective in preventing oviposition and suppressing nymph populations, so this aspect needs further investigation (Jurnal BioPesticides, 2017).
3. Observations were conducted over a relatively short period (4 applications), so the long-term effects of basil leaf extract use are not yet known.

4. The research has not tested basil leaf extract formulations with additional ingredients (adjuvants) to improve stability and effectiveness. Hussein et al.'s (2025) research showed that bioactivity data obtained under greenhouse conditions may not always be equivalent to *in vivo* toxicity, so further research on stability and long-term effects is needed (Hussein et al., 2025).

Further research is needed to address these limitations and optimize the utilization of basil leaf extract as an effective and efficient botanical pesticide. Development of integrated pest management strategies that integrate botanical pesticides with other control methods is highly recommended for sustainable whitefly control (ScienceDirect, 2025; Hussein et al., 2025).

CONCLUSION

Based on the results and discussion, the following conclusions can be drawn:

1. Basil leaf extract (*Ocimum basilicum*) is effective in controlling whitefly (*Bemisia tabaci*) populations and attack intensity on red chili plants. The 75% basil leaf extract treatment suppressed whitefly populations by 70.6% and attack intensity by 74.5% compared to the control.
2. The optimal concentration of basil leaf extract as a botanical pesticide for controlling whitefly pests is 50-75%. Excessively high concentrations (100%) actually reduce effectiveness due to uneven solution spreading power.
3. Basil leaf extract at 75% concentration provides effectiveness approaching that of synthetic chemical insecticide (deltamethrin 0.05%) in controlling whitefly pests and increasing red chili yields.
4. The mechanism of action of basil leaf extract as a botanical pesticide includes contact poison, respiratory poison, stomach poison, antifeedant, and repellent effects caused by active compounds such as flavonoids, saponins, tannins, and eugenol.
5. The utilization of basil leaf extract as a botanical pesticide is an environmentally friendly pest control alternative that is safe for health and can be produced independently by farmers.

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