



Effect of Botanical Pesticides on Inhibiting *Colletotrichum* sp. Causing Anthracnose in Avocado (*Persea americana* Mill.) In Vitro

Anisa Rahman Rusiati¹, Feskaharny Alamsjah^{1*}, Riska², Suwirmen¹

¹ Department of Biology, Faculty of Mathematics and Natural Science, Universitas Andalas, Padang, Indonesia.

² Research Center for Horticultural, National Research and Innovation Agency, Bogor, Indonesia.

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Corresponding Author:

Feskaharny Alamsjah

feskha@sci.unand.ac.id

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Abstract: Anthracnose caused by *Colletotrichum* sp. is a major postharvest disease of avocado (*Persea americana* Mill.) that leads to significant economic losses during storage. This study aimed to evaluate the antifungal efficacy of essential oil-based botanical pesticides derived from lemongrass (*Cymbopogon nardus* L.), cinnamon (*Cinnamomum burmannii* L.), and wild betel (*Piper aduncum* L.) against *Colletotrichum* sp. in vitro. The experiment was arranged in a Completely Randomized Design (CRD) with nine treatments and three replications, using essential oil concentrations up to 1000 ppm in both single and combined formulations. Antifungal activity was assessed based on colony diameter and fungal biomass, and data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's New Multiple Range Test (DNMRT). All treatments significantly inhibited fungal growth compared to the control. The smallest colony diameter was recorded in the lemongrass treatment (12.80 mm), with the highest inhibition rate of 85.77%. The lowest fungal biomass was observed in the cinnamon treatment (20 mg). These results demonstrate very strong antifungal activity of the tested essential oils. This study highlights the novelty of utilizing locally sourced essential oils as botanical pesticide formulations targeting *Colletotrichum* sp., suggesting their potential as environmentally friendly alternatives for sustainable postharvest disease management.

Keywords: Anthracnose; Avocado; *Colletotrichum* sp.; Essential oil; Botanical pesticide

Introduction

Avocado (*Persea americana* Mill.) is one of the horticultural crops with high economic value. The nutritional content of avocados is quite high, making them highly sought after and a target export commodity (Marsigit, 2016). Avocados are also one of Indonesia's leading export commodities, with total exports exceeding 400 tons per year (Directorate General of Horticulture, 2024), and there is still significant potential to increase the value of these exports. However, despite efforts to meet export demand, avocado farmers and suppliers still face high levels of fruit damage in the supply chain. One of the major causes of this damage is anthracnose disease during storage, which significantly

reduces fruit quality and marketability, leading to substantial economic losses (Bustamante et al., 2022).

A total of 20 *Colletotrichum* species have been reported as causes of anthracnose disease (Bustamante et al., 2022). Symptoms of anthracnose disease are characterized by the formation of round lesions that are initially brown in color but later enlarge and turn dark brown to black (Sarkhosh et al., 2017). A common method used to control anthracnose disease in avocados is the use of synthetic fungicides. However, continuous use of synthetic fungicides will have an impact on environmental damage and cancer health (Sharma & Singhvi, 2017; Budiyo, 2018; Sasmita et al., 2025). In addition, this practice may contribute to the development of fungal resistance, requiring higher

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application rates that can exceed the recommended doses. Therefore, the use of biological agents, such as biofungicides, represents an appropriate and safer alternative for controlling pathogenic microorganisms that cause diseases in cultivated plants (Asharo et al., 2024).

Botanical pesticides have emerged as a promising alternative to synthetic fungicides for controlling postharvest diseases such as anthracnose during storage and transportation of infected fruits. These pesticides are considered more environmentally friendly, safer for human health, and readily available due to their natural plant-based origins (Fakhrudin et al., 2023). Essential oils derived from various plants are the primary source of botanical pesticides and have been widely reported to exhibit antifungal and antibacterial activities against diverse plant pathogens (Mbatu et al., 2018; Awaluddin et al., 2023). Numerous studies have demonstrated their effectiveness, including cinnamon essential oil inhibiting *Fusarium oxysporum* (Nurmansyah et al., 2024), as well as citronella and water hyacinth essential oils suppressing *Curvularia lunata* (Setyawati et al., 2024). Mechanistically, the antifungal activity of essential oils is mainly attributed to terpenoid compounds, which can penetrate fungal cell walls, inhibit mycelial formation, shorten hyphal tips, disrupt cellular metabolism, induce lipid accumulation in the cytoplasm, reduce mitochondrial numbers, and damage the nuclear membrane (Nurmansyah et al., 2023).

Further empirical evidence supports the application of essential oil-based formulations in plant disease management. Essential oils of citronella and wild betel at 1000 ppm showed strong inhibitory effects against *Phytophthora palmivora* in cacao (Nasir et al., 2017), while also suppressing *Fusarium* sp. and *Ganoderma boninense* (Panjaitan et al., 2023). Combinations of wild betel essential oil with cinnamon, clove, or citronella demonstrated high antifungal efficacy against *Fusarium oxysporum* f. sp. *cubense*, the causal agent of *Fusarium* wilt in banana (Nurmansyah et al., 2023). Additionally, cinnamon essential oil has been reported to inhibit *Neoscytalidium dimidiatum*, the causal agent of stem canker in dragon fruit, as well as *F. oxysporum* (Okina et al., 2024). However, studies evaluating the combined effects of citronella, cinnamon, and wild betel essential oils specifically against *Colletotrichum* sp. associated with avocado anthracnose remain limited, indicating a clear research gap.

The selection of lemongrass, cinnamon, and wild betel essential oils is based on their complementary bioactive compounds, particularly terpenoids and phenolic constituents, which are known to disrupt fungal cell structures and metabolic processes. The combination of these oils is expected to enhance

antifungal activity through synergistic mechanisms (Sakinah et al., 2021; Juariah et al., 2025).

Therefore, this study aimed to evaluate the antifungal effectiveness of single and combined essential oil-based botanical pesticide formulations against *Colletotrichum* sp. in vitro. It was hypothesized that combined formulations would exhibit higher inhibitory activity compared to single treatments. The novelty of this study lies in the evaluation of ready-to-use formulations developed by BRIN, integrating locally sourced essential oils in both single and combined forms specifically targeting *Colletotrichum* sp. associated with avocado anthracnose. The findings are expected to contribute to the development of environmentally friendly and practical alternatives for postharvest disease management.

Method

Time and Location of the Research

This research was conducted from November 2024 to February 2025 at the Microbiology Research Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Andalas, Padang.

Research Methods

This study employed a Completely Randomized Design (CRD) consisting of nine treatments with three replications, using essential oil concentrations of up to 1000 ppm. A: Citronella essential oil formulation; B: Cinnamon essential oil formulation; C: Wild betel essential oil formulation; D: Citronella + cinnamon formulation; E: Citronella + wild betel formulation; F: Cinnamon + wild betel formulation; G: Citronella + cinnamon + wild betel formulation; Positive control (+): Application of fungicide (Propineb 0.2%); Negative control (-): Without botanical pesticide application.

Research Stages

Flowchart Stage of Research

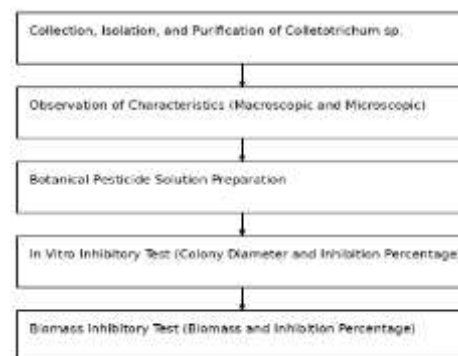


Figure 1. Flowchart stage of research

Collection, Isolation, and Purification of Colletotrichum sp.

Samples were taken from ripe avocados from farmers' fields in Solok. The harvested fruit was then cleaned of dirt with gauze and sprayed with 70% alcohol over the entire surface of the fruit. The fruit was then placed in a clean plastic container lined with moist tissue paper, sealed, and incubated for approximately 6 days at room temperature until anthracnose symptoms appeared, which were observed visually. During isolation, the fruit surface was sterilized again by wiping the fruit skin with tissue paper moistened with 70% alcohol. Next, a sample piece of approximately 0.5 cm² is taken from the fruit surface between the healthy and diseased parts and grown in a petri dish containing PDA medium and incubated for 7 days at room temperature (27°C) (Rusman et al., 2023). The fungal isolate suspected to be *Colletotrichum* is further purified by growing it on new PDA medium (Huda et al., 2019). The Koch's postulates were then performed by sterilizing healthy avocado fruit, then inoculating it with the suspected *Colletotrichum* isolate on the surface of the damaged fruit. The fruit was then incubated for 6 days at 27°C, and fungal growth was observed and compared with infection symptoms in the field and reinoculated (Fitriyah et al., 2023).

Observation of the Characteristics of Colletotrichum sp.

The morphological characterization of *Colletotrichum* sp. fungi observed included macroscopic and microscopic observations. Macroscopic characterization of the fungi was performed by visually observing the shape of the colony, the surface of the colony, and the color of the colony. Meanwhile, microscopic characterization observed the shape of the hyphae, the shape of the spores, and their size (Wulandari et al., 2025). Microscopic observations of the fungus were conducted under a Binocular microscope at 40x magnification.

Botany Pesticide Solution.

The botanical pesticide derived from lemongrass, cinnamon, and forest betel leaves was developed by researchers at the National Research and Innovation Agency (BRIN) and is a ready-made formulation. The formulation contains 25% essential oil as the main ingredient, 63% solvent (Terpentine), 10% emulsifier (Tween 80), 2% (Teepol) moisturizer, and the concentration is adjusted to 100%. The formula is stirred with a stirrer for 20 minutes. It is then stored in a dark bottle, and the formulation is ready for testing (Nurmansyah et al., 2023).

Testing the Inhibitory Effect of Botanical Pesticides on the Growth of Colletotrichum sp. in Vitro.

The test was conducted by mixing each botanical pesticide formulation at a concentration of 1000 ppm into 100 ml of sterile PDA in an Erlenmeyer flask [10]. Ten milliliters of the PDA and essential oil formulation mixture were poured into 9 cm petri dishes [18]. Next, a 5 mm diameter isolate of *Colletotrichum* sp. that had been purified was taken using a cork borer and placed in the center of the petri dish containing the PDA medium according to the treatment. The cultures were incubated for several days at 27°C. Observations were conducted on the first, third, fifth, and seventh days after inoculation by measuring the diameter of fungal colony growth in each treatment. Observations were stopped when the fungal colony diameter had covered the entire PDA surface in the petri dish in the control treatment (Nasir et al., 2017). The inhibitory effect of botanical pesticides on the growth of *Colletotrichum* sp. colonies was calculated based on the measured diameter of fungal colonies in the petri dish. The percentage of inhibition by botanical pesticides was calculated using the formula according:

$$P = \frac{Dc - Dt}{Dc} \times 100 \% \quad (1)$$

Testing the Inhibitory Effect of Botanical Pesticide Formulations on Fungal Biomass

For the colony biomass experiment, 25 ml of liquid Potato Dextrose Broth (PDB) medium was placed in 9 test tubes, covered with aluminum foil, and sterilized at 121°C, 1.5 atm for 20 minutes. After the medium cooled ($\pm 50^\circ\text{C}$), the botanical pesticide formulation was added at the treatment concentration. *Colletotrichum* sp. isolates were inoculated using 5 mm pieces of mycelium from sterile cork borer. The cultures were incubated at 28°C for 8 days. The growing colonies were harvested and dried at 80°C for 48 hours or until the weight stabilized, then weighed to assess the inhibition effectiveness (Nurmansyah et al., 2023a). To calculate the inhibition of colony biomass, the following formula was used:

$$I = \frac{c-T}{c} \times 100 \% \quad (2)$$

Data Analysis

The data obtained included macroscopic and microscopic characteristics of fungi, colony diameter, colony growth inhibition, and colony biomass. Macroscopic and microscopic characteristics were analyzed descriptively. Meanwhile, data on colony diameter, growth inhibition, and biomass were analyzed using analysis of variance (ANOVA) (Haryani et al., 2025). If there were significant differences between treatments, Duncan's New Multiple Range Test

(DNMRT) was conducted at a significance level of 5% (Julyasih et al., 2025).

Result and Discussion

Characteristics of Colletotrichum sp. Fungi that Cause Anthracnose in Avocados

Avocado samples incubated for 6 days at room temperature showed changes on the surface of the fruit skin. Avocado fruits that were previously green exhibited symptoms in certain areas. Isolation from the symptomatic fruit skin yielded fungal colonies that were grayish-white in color, round in shape with smooth edges, and had a cotton-like texture. On day 3, these colonies produced orange-colored conidiophores, a characteristic feature of the *Colletotrichum* group, show in Figure 2. The pathogen was confirmed using Koch's postulates, where healthy avocado fruits inoculated with the fungus exhibited similar symptoms, and the same fungus was successfully reisolated. These results indicate that the fungus is the cause of anthracnose in avocado fruits. The symptoms caused by anthracnose are in the form of dark, depressed lesions (Baba et al., 2019).

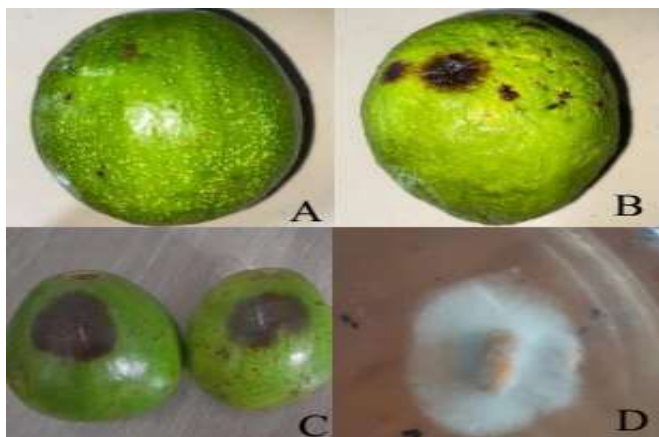


Figure 2. Koch's Postulates Process, A) Fruit before symptoms, B) Symptomatic fruit, C) Results of Koch's Postulates, D) *Colletotrichum* re-isolation

The isolate exhibited grayish-white fungal colonies with a round shape, smooth edges, and a cotton-like texture. On the third day, the colonies began to produce orange conidiomata, which are characteristic of the *Colletotrichum* group. The macroscopic and microscopic characteristics of the isolate are shown in Figure 3.

Macroscopically, fungi growing on PDA medium form dense, cotton-like colonies that are white in color with smooth edges and produce orange conidiomata. Microscopically, observation with a trinocular microscope reveals cylindrical, hyaline, single-celled conidia measuring 10–17 μm in length and approximately 2.8 μm in diameter, as well as septate

hyphae with diameters ranging from 2.8–6.4 μm . Based on the results of macroscopic and microscopic morphological observations, the fungal isolate belongs to the genus *Colletotrichum*, characterized by hyaline conidia, single-celled, oval or elongated in shape, and setae shaped like discs or cushions, waxy, subepidermal, often with spines or dark-colored setae along the edges or along the conidiophores. Recent studies (Wiyanna S et al., 2022; Sari & Kasiamdari, 2021) also indicate that *Colletotrichum* sp. forms colonies on growth media ranging in color from grayish white to orange. It has cylindrical conidia and septate hyphae, as well as setae or acervuli.

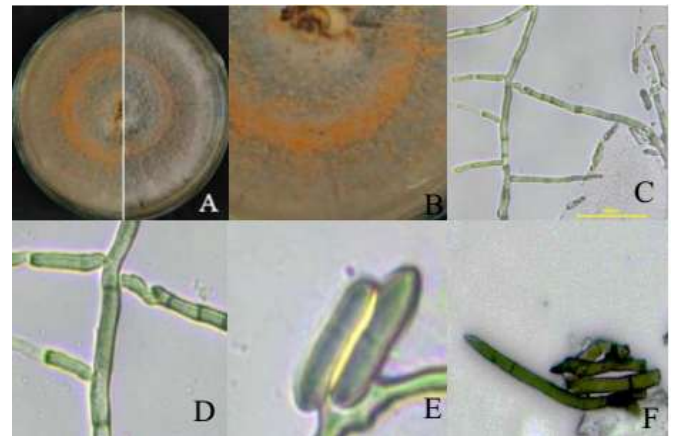


Figure 3. Characteristics of *Colletotrichum* sp. fungi, A) *Colletotrichum* sp. isolate, B) conidiomata, C) Microscopic view of *Colletotrichum* sp. (40x magnification), D) septate hyphae, E) conidia, F) setae

Inhibitory Effect of Botanical Pesticides on Colletotrichum sp. Fungi

In general, all essential oil formulations can suppress the growth of *Colletotrichum* sp. fungal colonies with no significant variation in the percentage of inhibition. The inhibitory effect of essential oil formulations is determined by measuring the diameter of fungal colonies.

The smallest colony diameter of *Colletotrichum* sp. was obtained with the botanical pesticide lemongrass essential oil, measuring 12.80 mm, which was not significantly different from the botanical pesticides lemongrass + cinnamon, lemongrass + forest betel, cinnamon + forest betel, and lemongrass + cinnamon + forest betel. However, the botanical pesticide lemongrass essential oil was significantly different from the botanical pesticides cinnamon and forest betel leaf alone. The botanical pesticide lemongrass essential oil produced the largest colony diameter of 43.69 mm, which was significantly different from the other treatments. Nevertheless, all treatments had smaller colony diameters and were significantly different compared to the positive and negative controls.

Table 1. Average Colony Diameter and Percentage of Inhibition of Botanical Pesticide Formulations Against *Colletotrichum* sp. Colonies After 8 *ays of Incubation

Treatment	Colony diameter (mm)	Inhibitory Power Percentage (%)
A. Formulation of lemongrass essential oil	12.80 a	85.77 d
B. Formulation of cinnamon essential oil	43.69 c	51.45 c
C. Formulation of forest betel essential oil	25.22 b	71.97 d
D. Formulation of lemongrass + cinnamon	22.11 ab	75.43 d
E. Formulation of lemongrass + forest betel	15.5 ab	82.78 d
F. Formulation of cinnamon + forest betel	17.25 ab	80.83 d
G. Formulation of lemongrass + cinnamon + forest betel	13.63 a	84.85 d
Positive control	63.5 cd	29.44 b
Negative control	90 d	0 a

Note: Numbers followed by different letters indicate significant differences in the DNMRT 5% test.

According to antifungal activity is categorized as very strong with an inhibition percentage of 76–100% and strong from 51–75%. Based on this categorization, the inhibitory power of treatments with lemongrass essential oil, lemongrass + forest betel, cinnamon + forest betel, and lemongrass + cinnamon + forest betel is classified as very strong, while cinnamon, cinnamon, and forest betel are classified as strong. Table 1 shows that the smaller the colony diameter, the higher the inhibitory power, in accordance with the findings of (Widianti et al., 2023). The slowdown in the growth of *Colletotrichum* sp. colonies on media containing lemongrass essential oil is thought to be caused by the

antimicrobial compounds contained in the botanical pesticide used, which effectively inhibits fungal growth (Fatmia et al., 2023).

Inhibitory Effect of Botanical Pesticides on the Biomass of Colletotrichum sp. Fungi

Observations of *Colletotrichum* sp. biomass after the incubation period showed that treatment with essential oil-based botanical pesticides was able to suppress fungal growth. In general, the biomass values for all treatments showed a downward trend, indicating the antifungal activity of each formulation.

Table 2. The Inhibitory Effect of Botanical Pesticide Formulations on *Colletotrichum* sp. Biomass After 8 Days of Incubation

Treatment	Biomass (mg)	Inhibitory Power Percentage (%)
A. Formulation of lemongrass essential oil	26.00 a	79.20 c
B. Formulation of cinnamon essential oil	20.00 a	84 c
C. Formulation of forest betel essential oil	26 a	79.20 c
D. Formulation of lemongrass + cinnamon	30 a	76 c
E. Formulation of lemongrass + forest betel	23 a	81.6 c
F. Formulation of cinnamon + forest betel	26 a	79.2 c
G. Formulation of lemongrass + cinnamon + forest betel	23 a	81.6 c
Positive control	86 b	31.2 b
Negative control	125 b	0 a

Note: Numbers followed by different letters indicate significant differences in the DNMRT 5% test.

Table 2 shows that the biomass of *Colletotrichum* sp. and its inhibition percentage did not differ significantly between the essential oil formulations, but differed significantly from the control. This lack of difference indicates that each essential oil contains effective antifungal compounds. Lemongrass essential oil contains citronellal, citronellol, and geraniol, which have high antimicrobial activity. Citronellal works by inhibiting ergosterol synthesis, a major component of fungal cell membranes (Pannyiwi et al., 2023). The results of the study by Zhou et al. (2023) also reported that citronellal can damage the cell walls of *Magnaporthe oryzae* by increasing the expression of genes related to chitinase and β -1,3-glucanase, significantly enhancing chitinase activity, thereby disrupting chitin synthesis,

damaging cell walls, and ultimately inhibiting fungal mycelium growth. Additional components such as α -pinene, linalool, β -caryophyllene, and elemol enhance its antifungal properties. The synergistic interaction between these active compounds strengthens the fungistatic and fungicidal effects (Lely et al., 2018).

Cinnamon oil contains cinnamaldehyde, alkaloids, saponins, and tannins (Prambudi & Supriyatin, 2025; Megawati et al., 2025). Cinnamaldehyde is known to have a broad spectrum of activity in inhibiting the growth of post-harvest pathogens such as *Candida albicans* (Rizki & Panjaitan, 2018) and *Aspergillus niger* (Wang et al., 2023) through damage to cell walls and membranes. Forest betel oil contains dillapiole, which can damage the permeability of fungal cell membranes,

causing the loss of important proteins and cell death. Cinnamaldehyde exhibits broad-spectrum antifungal activity in inhibiting the growth of postharvest fruit pathogens (Yang et al., 2020).

According to Sakinah et al. (2021), interactions between compounds in essential oils can be synergistic, antagonistic, additive, or indifferent. A synergistic effect occurs when the combination of compounds provides stronger activity than when used individually. The results of the study by Hadiyah et al. (2017) also stated that similar active compounds can support each other through synergistic mechanisms. However, in this study, the combination treatment of two and three essential oils did not show significant differences compared to the single treatment of lemongrass. Therefore, the use of single essential oils, especially lemongrass, can be a more economical and practical choice for field applications.

Conclusion

From the research conducted, it can be concluded that botanical pesticides can inhibit the growth of *Colletotrichum* sp., with inhibition levels reaching up to 85.77%. Lemongrass essential oil showed the highest antifungal activity, indicated by the smallest colony diameter (12.80 mm) and the highest inhibition percentage, while cinnamon essential oil resulted in the lowest fungal biomass (20 mg). These findings demonstrate strong to very strong antifungal activity against *Colletotrichum* sp., the causal agent of anthracnose in avocado (*Persea americana* Mill.). The results indicate that locally sourced essential oils, applied individually or in combination, have potential as environmentally friendly alternatives to synthetic fungicides, particularly for postharvest disease management during storage and transportation. However, this study was conducted under in vitro conditions, which may not fully represent field conditions. Further research is required to evaluate their effectiveness in vivo, including optimization of dosage, formulation stability, and application methods for practical use in avocado production systems.

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Author Contributions

Conceptualization, A.R.R. and F.A.; methodology, A.R.R. and R.; software, A.R.R.; validation, A.R.R., F.A. and R.; formal analysis, A.R.R. and R.; investigation, A.R.R.; resources, S.; data curation, A.R.R.; writing—original draft preparation, A.R.R.; writing—review and editing, F.A. and R.; visualization, A.R.R.; supervision, F.A. and R.; project administration, F.A.; funding acquisition, F.A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

No conflict of interest.

References

- Asharo, R. K., Indrayanti, R., Amala, A., Raihan, E. D., Tampanguma, R. R., Putri, H. A. E., Pasaribu, P. O., & Wardana, N. A. (2024). Isolation and Characterization of Pathogenic Mold Causing Potato Tuber Rot Disease. *Jurnal Penelitian Pendidikan IPA*, 10(4), 1506–1512. <https://doi.org/10.29303/jppipa.v10i4.6355>
- Awaluddin, N., Awaluddin, S. W., Bachri, N., & Mointi, S. S. (2023). Formulation of Reed Diffuser is A Combination of Cinnamon (*Cinnamomum Verum*) and Citronella (*Cymbopogon Nardus*) Essential Oil as An Anti-Stress Aromatherapy. *Jurnal Penelitian Pendidikan IPA*, 9(4), 1960–1967. <https://doi.org/10.29303/jppipa.v9i4.3446>
- Baba, V. Y., Constantino, L. V., Ivamoto, S. T., Moreira, A. F. P., Madeira, T. B., Nixdorf, S. L., Rodrigues, R., & Gonçalves, L. S. A. (2019). *Capsicum-Colletotrichum* interaction: Identification of resistance sources and quantification of secondary metabolites in unripe and ripe fruits in response to anthracnose infection. *Scientia Horticulturae*, 246, 469–477. <https://doi.org/10.1016/j.scienta.2018.11.011>
- Budiyono, M. A. K. (2018). *Making organic fungicide*. Muhammadiyah University Press, Malang.
- Bustamante, M. I., Osorio-Navarro, C., Fernández, Y., Bourret, T. B., Zamorano, A., & Henríquez-Sáez, J. L. (2022). First Record of *Colletotrichum anthrisci* Causing Anthracnose on Avocado Fruits in Chile. *Pathogens*, 11(10), 1204. <https://doi.org/10.3390/pathogens11101204>
- Directorate General of Horticulture, K. P. (2024). *Fixed Figures of Horticulture 2023*. Directorate General of Horticulture, Ministry of Agriculture.
- Fakhrudin, J., Ali, M., Yama, D. I., Muliani, M., Susana, S., Mutaqin, Z., Yunita, T. R., Delyani, R., Ardianti,

- N., & Naturindo, N. (2023). Improving Skills in Organic Crop Cultivation through Training on the Production of Botanical Pesticides and Compost Fertilizer. *Prima Abdika: Journal of Community Service*, 3(4), 390-397. <https://doi.org/10.37478/abdika.v3i4.3205>
- Fatmia, B., Lakani, I., & Edy, N. (2023). Inhibitory Effect of Citronella (*Cymbopogon nardus* L.) Extract on the Growth of the Fungal Pathogen *Colletotrichum capsici*, the Causal Agent of Anthracnose Disease in Chili (*Capsicum annuum*), under In Vitro Conditions. *E-J. Agrotekbis*, 11(1). Retrieved from <https://jurnal.faperta.untad.ac.id/index.php/agrotekbis/en/article/view/1601?articlesBySameAuthorPage=2>
- Fitriyah, W., Ketut Sudirga, S., Made Gari, N. (2023). Effectiveness Of Cinnamon (*Cinnamomum burmanni* Blume) Leaf Extract In Inhibiting The Growth Of The Mushrooms *Colletotrichum magnum* Rossman & Allen Causes Of Anthracnose Disease In Papaya (*Carica papaya* Linnaeus). *SIMBIOSIS Journal of Biological Sciences*, (1), 105-117. <https://doi.org/10.24843/JSIMBIOSIS.2022.v11.i01.p09>
- Haryani, T. S., Nurfajriah, M. S., Sudrajat, C., Rezaldi, F., Yudianto, T., Ginaris, R. P., & Rahmad, S. S. (2025). Potential of Hanjeli (*Coix lacryma-jobi*) as an antifungal *Microsporum Gypseum* Causes Skin Infections: Extract, Boiled Water, Kombucha, and Bath Soap. *Jurnal Penelitian Pendidikan IPA*, 11(7), 108-117. <https://doi.org/10.29303/jppipa.v11i7.11744>
- Hodiyah, I., Hartini, E., Amilin, A., & Yusup, M. F. (2017). Antifungal Activity of Soursop (*Annona muricata*) Leaves, Siam Weed (*Chromolaena odorata*), and Galangal (*Alpinia galanga*) Rhizome Extracts against the Colony Growth of *Colletotrichum acutatum*. *AGRO Journal*, 4(2), 80-89. <https://doi.org/10.15575/1373>
- Huda, N., Imangsih, W., & Hakim, S. S. (2019). Antagonistic Test of Endophytic Fungi from Galam (*Melaleuca cajuputi*) against *Colletotrichum truncatum*. *Indonesian Mycological Journal*, 3(2), 59-74. <https://doi.org/10.46638/jmi.v3i2.62>
- Juariah, S., Juliansyah, R., & Wahyuni, N. (2025). Isolation and Antimicrobial Activity Test of n-Hexane of Pineapple Core *Ananas comosus* L. Merr. *Jurnal Penelitian Pendidikan IPA*, 11(3), 737-744. <https://doi.org/10.29303/jppipa.v11i3.10696>
- Julyasih, K. S. M., Parwata, I. P., & Pertiwi, N. P. D. (2025). Differences in the Percentage of Fusarium Wilt Disease Attacks and High Vegetative Growth of Purple Eggplant (*Solanum melongena* L.) Plants with Various Concentrations of Antagonist Fungus *Trichoderma harzianum*. *Jurnal Penelitian Pendidikan IPA*, 11(8), 153-160. <https://doi.org/10.29303/jppipa.v11i8.12090>
- Lely, N., Sulastri, H., & Meisyayati, S. (2018). Activity Antifungi Of Oil Atsiri Sereh Wangi (*Cymbopogon Nardus* (L) Rendle). *Jurnal Kesehatan Saemakers PERDANA (JKSP)*, 1(1), 31-37. Retrieved from <http://ojs.ukmc.ac.id/index.php/JOH>
- Marsigit, W. (2016). Morphometric Characteristics, Proportition, Total Fenol Content and Profil Phenolics Of Avocado (*Persea americana*, Mill) Pulp, Seed And Peel Variety Of Ijo Panjang And Ijo Bundar. *Jurnal Agroindustri*, 18(1). <https://doi.org/10.31186/j.agroind.6.1.18-27>
- Mbatu, R. S. T., Kenanda, I. P. B., & Suharta, I. G. Y. (2018). Antifungal activity of clove leaf essential oil against *Candida albicans*. *Jurnal Media Sains*, 2(1). <https://doi.org/10.36002/jms.v2i1.360>
- Megawati, S., Safitri, M., Huwaida, Z., & Sylvia, D. (2025). Antibacterial Activity of Combined Essential Oils of Cinnamon (*Cinnamomum verum*) and Tamanu (*Calophyllum inophyllum*) Against Acne-Causing Bacteria. *Jurnal Penelitian Pendidikan IPA*, 11(11), 1151-1156. <https://doi.org/10.29303/jppipa.v11i11.10984>
- Nasir, N., Putria Murza, V., Agustien, A., & Alamsjah, F. (2017). In-vitro Consistently Biopesticide Effects of Piper aduncum and *Cymbopogon flexuosus* Essential Oils against *Phytophthora palmivora* Colony Growth. *Der Pharmacia Lettre*, 9, 95-104. Retrieved from <http://scholarsresearchlibrary.com/archive.html>
- Nurmansyah, Agustien, A., & Mansyurdin. (2023). Potential of essential oil pesticides for controlling *Fusarium oxysporum* causing wilt disease in cultivated plants. *Jurnal Agrosains dan Teknologi*, 8(2), 94-103. <https://doi.org/10.24853/jat.8.2.94-103>
- Nurmansyah, Idris, H., & Riska. (2023). Effect of various formulations of *Piper aduncum* botanical pesticide and concentration levels on fungal pathogen *Fusarium oxysporum* f.sp. *cubense* Vegetative Compatibility Group (VCG) 01213/16 Tropical strain 4 and VCG 01218 strain 1. *IOP Conference Series: Earth and Environmental Science*, 1253(1), 012014. <https://doi.org/10.1088/1755-1315/1253/1/012014>
- Nurmansyah, Idris, H., Agustien, A., Mansyurdin, & Riska. (2024). Antifungal effectiveness of some essential oils and their mixtures against *Fusarium oxysporum* f.sp. *cubense* that causes fusarium wilt disease of banana plants. *BIO Web of Conferences*, 99, 04002. <https://doi.org/10.1051/bioconf/20249904002>

- Okina, E., Sulhaswardi, & Rizka. (2024). In Vitro Control of *Neoscytalidium dimidiatum* Using Cinnamon Essential Oil in Dragon Fruit (*Hylocereus* sp.). *Dynamics of Agriculture.*, 39(3), 187-192. [https://doi.org/10.25299/dp.2023.vol39\(3\).16431](https://doi.org/10.25299/dp.2023.vol39(3).16431)
- Panjaitan, R., Siahaan, J., & Julyanthry, J. (2025). The influence of green banking and esg practices on financial performance. *Jurnal Ilmiah Akuntansi Kesatuan*, 13(3), 545-554. Retrieved from <http://agronita.usxiitapanuli.ac.id>
- Pannyiwi, R., Kasiyati, M., Martiningsih, M. A., Syariah, S. N., Suyana, S., Pudyastuti, R. R., & Sujono, S. (2023). Inhibitory Test Of Citronella Essential Oil (*Cymbopogon nardus* L. Rendle) Against *Aspergillus flavus* Growth. *Indonesian Journal Of Health Sciences Research And Development (IJHSRD)*, 5(1), 21-29. <https://doi.org/10.36566/ijhsrd/Vol5.Iss1/143>
- Prambudi, H., & Supriyatin. (2025). Review of Essential Oil Bioactivity Against Anxiety Symptom. *Jurnal Penelitian Pendidikan IPA*, 11(6), 1-9. <https://doi.org/10.29303/jppipa.v11i6.11512>
- Rizki, S. M., & Panjaitan, R. S. (2018). Antifungal Activity of Essential Oil from Cinnamon Bark (*Cinnamomum burmannii*) against *Candida albicans*. *EduChemia (Journal of Chemistry and Education)*, 3(2), 172. <https://doi.org/10.30870/educhemia.v3i2.4560>
- Rusman, H., Alim, N., & Rahma, N. R. (2023). Characterization of Endophytic Fungi in Robusta Coffee (*Coffea canephora* L.) Beans Through 18S rRNA Gene Sequencing and Evaluation of Antioxidant Activity and Chlorogenic Acid Content. *Jurnal Penelitian Pendidikan IPA*, 9(11), 9964-9972. <https://doi.org/10.29303/jppipa.v9i11.5106>
- Sakinah, N., Rialita, T., Subroto, E. (2021) Review of interactions of various combinations of essential oils against food spoilage microorganisms: A literature study. *Jurnal Sains dan Teknologi Pangan*, 6(4), 4180-4191. Retrieved from <https://ojs.uho.ac.id/index.php/jstp/article/view/>
- Sari, N., & Kasiamdari, R. S. (2021). Identification and Pathogenicity Test of *Colletotrichum* spp. from Red Chili (*Capsicum annuum*): A Case in Kricaan, Magelang, Central Java. *Journal of Indonesian Agricultural Science*, 26(2), 243-250. <https://doi.org/10.18343/jipi.26.2.243>
- Sarkhosh, A., Vargas, A. I., Schaffer, B., Palmateer, A. J., Lopez, P., Soleymani, A., & Farzaneh, M. (2017). Postharvest management of anthracnose in avocado (*Persea americana* Mill.) fruit with plant-extracted oils. *Food Packaging and Shelf Life*, 12, 16-22. <https://doi.org/10.1016/j.fpsl.2017.02.001>
- Sasmita, M., Marwoto, P., Nugroho, S. E., & Sumarni, W. (2025). Antifungal Activity of Ethanol Extract of Stem Bark And Fruit Flesh of *Baccaurea lanceolata* Against Fungi Causing Skin Infections. *Jurnal Penelitian Pendidikan IPA*, 11(5), 222-232. <https://doi.org/10.29303/jppipa.v11i5.10075>
- Setyawati, F. D., & Yuliani, Y. (2024). Biofungicide activity of citronella (*Cymbopogon nardus* L.) and water hyacinth (*Eichhornia crassipes*) extracts in inhibiting the growth of *Curvularia lunata*. *LenteraBio: Berkala Ilmiah Biologi*, 13(1), 32-43. <https://doi.org/10.26740/lenterabio.v13n1.p32-43>
- Sharma, N., & Singhvi, R. (2017). Effects of Chemical Fertilizers and Pesticides on Human Health and Environment: A Review. *International Journal of Agriculture, Environment and Biotechnology*, 10(6), 675. <https://doi.org/10.5958/2230-732X.2017.00083.3>
- Wang, M., Liu, H., Dang, Y., Li, D., Qiao, Z., Wang, G., Liu, G., Xu, J., & Li, E. (2023). Antifungal Mechanism of Cinnamon Essential Oil against Chinese Yam-Derived *Aspergillus niger*. *Journal of Food Processing and Preservation*, 2023, 1-9. <https://doi.org/10.1155/2023/5777460>
- Widianti, R. A., Nofita, & Yasir, S. A. (2023). Formulasi Sediaan Salep Ekstrak Etanol Daun Alpukat (*Persea americana* Mill.) Sebagai Antiacne Terhadap Bakteri *Staphylococcus aureus*. *Jurnal Ilmiah Wahana Pendidikan*, 9(7), 722-732. <https://doi.org/10.5281/zenodo.10151862>
- Wiyanna, S., Rahmawati, & Mukarlina. (2022). Morphological characteristics of *Aspergillus* and *Colletotrichum* associated with symptomatic leaves of Siam citrus (*Citrus nobilis* var. *microcarpa*) in citrus plantations in Singkawang City. *Jurnal Mikologi Indonesia*, 6(1), 9-14. <https://doi.org/10.46638/jmi.v6i1.179>
- Wulandari, F. A., Sukamto, D. S., & Putri, H. R. (2025). Characterization of Orchid Root Fungal Isolates as Leaflet Teaching Material to Improve Learning Outcomes of Grade X Vocational High School Students on the Subtopic of Kingdom Fungi. *Jurnal Penelitian Pendidikan IPA*, 11(5), 202-214. <https://doi.org/10.29303/jppipa.v11i5.10934>
- Yang, Q., Okwong, R. O., Chen, Y., & Tao, N. (2020). Synergistic activity of cinnamaldehyde and citronellal against green mold in citrus fruit. *Postharvest Biology and Technology*, 162, 111095. <https://doi.org/10.1016/j.postharvbio.2019.111095>
- Zhou, H., Chen, X., Liang, H., Liu, M., Zu, X., Lu, Y., Zhou, J., Yang, S., Yu, L., Liu, E., & Ren, Z. (2023). Identification and whole-genome sequencing of a bacterial strain isolated from healthy rice plants

antagonistic to *Magnaporthe oryzae*. *Physiological and Molecular Plant Pathology*, 128, 102129.
<https://doi.org/10.1016/j.pmpp.2023.102129>