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The Effect of Botanical Pesticides on Pest Infestation Levels

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ABSTRAK

Penelitian ini bertujuan untuk menganalisis pengaruh penggunaan pestisida nabati terhadap tingkat serangan hama di Indonesia dengan menggunakan pendekatan kuantitatif. Data dikumpulkan dari 65 responden yang terlibat dalam kegiatan pertanian melalui kuesioner terstruktur yang didasarkan pada skala Likert. Penelitian ini berfokus pada pengukuran persepsi responden mengenai penggunaan, efektivitas, dan dampak lingkungan dari pestisida nabati, serta tingkat serangan hama yang dialami. Analisis data dilakukan menggunakan SPSS Versi 25, termasuk statistik deskriptif, uji validitas dan reliabilitas, serta analisis regresi linier sederhana. Hasil menunjukkan bahwa penggunaan pestisida nabati memiliki pengaruh negatif yang signifikan terhadap tingkat serangan hama, dengan koefisien regresi sebesar -0,278 dan nilai signifikansi 0,003 (< 0,05). Temuan ini menunjukkan bahwa peningkatan penggunaan pestisida nabati berkontribusi terhadap penurunan tingkat serangan hama. Koefisien determinasi (R^2) sebesar 0,135 menunjukkan bahwa 13,5% variasi tingkat serangan hama dapat dijelaskan oleh penggunaan pestisida nabati, sedangkan variasi sisanya dipengaruhi oleh faktor-faktor lain. Kesimpulannya, pestisida nabati merupakan alternatif yang efektif dan ramah lingkungan untuk pengendalian hama di Indonesia, meskipun dampaknya moderat dan harus diintegrasikan dengan strategi pengendalian hama lainnya. Penelitian ini berkontribusi pada pengembangan pertanian berkelanjutan dengan memberikan bukti empiris mengenai peran pestisida nabati dalam mengurangi tingkat serangan hama.

Kata Kunci: *Pestisida Botani, Serangan Hama, Pertanian Berkelanjutan, Skala Likert, Analisis Kuantitatif*

ABSTRACT

This study aims to analyze the effect of botanical pesticide use on pest infestation rates in Indonesia using a quantitative approach. Data were collected from 65 respondents involved in agricultural activities through a structured questionnaire based on a Likert scale. The study focuses on measuring respondents' perceptions regarding the use, effectiveness, and environmental impact of botanical pesticides, as well as the level of pest infestation experienced. Data analysis was conducted using SPSS Version 25, including descriptive statistics, validity and reliability tests, and simple linear regression analysis. The results indicate that botanical pesticide use has a significant negative effect on pest infestation rates, with a regression coefficient of -0.278 and a significance value of 0.003 (< 0.05). This finding suggests that increased use of botanical pesticides contributes to a reduction in pest infestation levels. The coefficient of determination (R^2) of 0.135 indicates that 13.5% of the variation in pest infestation rates can be explained by botanical pesticide use, while the remaining variation is influenced by other factors. In conclusion, botanical pesticides are an effective and environmentally friendly alternative for pest management in Indonesia, although their impact is moderate and should be integrated with other pest control strategies. This study contributes to the development of sustainable agriculture by providing empirical evidence on the role of botanical pesticides in reducing pest infestation rates.

Keywords: *Botanical Pesticides, Pest Infestation, Sustainable Agriculture, Likert Scale, Quantitative Analysis*

INTRODUCTION

Agricultural productivity in Indonesia continues to face significant challenges, particularly due to pest infestations that can substantially reduce crop yields and quality. As an agrarian country with a tropical climate, Indonesia provides favorable conditions for the rapid growth and reproduction of various pests, including insects, fungi, and plant pathogens. This situation has led farmers to rely heavily on synthetic chemical pesticides due to their immediate effectiveness and ease of application. However, the excessive and prolonged use of these chemicals has resulted in serious consequences, such as environmental degradation, pest resistance, risks to human health, and disruption of ecological balance, thereby increasing the urgency to identify more sustainable pest control alternatives.

One promising alternative is the use of plant-based pesticides. Previous studies have demonstrated that papaya leaf extract (Carica papaya L.) is effective in controlling pests such as caterpillars and aphids, leading to healthier crops and reduced damage (Andira, Wibowo, Prissy, Carissa, & Wulan, 2025). In addition, other local plants such as neem, tobacco, and lemongrass have been identified as effective pest control agents, with neem showing strong pest resistance and the ability to improve crop yields (Listiyani, 2025; Sutriadi, Harsanti, Wahyuni, & Wihardjaka, 2019). From an environmental and health perspective, plant-based pesticides are biodegradable and do not leave harmful residues, making them safer for both ecosystems and human health (Harahap, Pasaribu, & Efendi, 2026). Furthermore, the adoption of these natural alternatives helps reduce dependence on synthetic pesticides, which are associated with biodiversity loss and increased pest resistance (Listiyani, 2025).

Beyond their technical advantages, the successful implementation of plant-based pesticides is also supported by participatory approaches and farmer education. Community-based programs have proven effective in enhancing farmers' knowledge and skills in utilizing natural resources for pest management, thereby promoting self-reliance (Andira et al., 2025). In recent years, there has been growing attention toward sustainable and environmentally friendly agricultural practices, including the use of botanical pesticides derived from plant materials such as leaves, seeds, roots, and extracts containing bioactive compounds. These pesticides are considered more environmentally friendly because they are biodegradable, less toxic to non-target organisms, and capable of reducing pest resistance. With the availability of local plants such as neem, tobacco, papaya leaves, and lemongrass, botanical pesticides represent a viable and relevant solution for advancing sustainable agriculture in Indonesia.

Despite their advantages, the adoption of botanical pesticides among farmers remains relatively limited, particularly in Indonesia, where perceptions of effectiveness compared to synthetic pesticides play a crucial role. Many farmers consider botanical pesticides to be slower-acting and less potent, which reduces their willingness to adopt these alternatives (Al Shamsi, 2024). In addition, misunderstandings about biopesticides—often associated solely with organic farming—contribute to skepticism and hesitation (Sumartini, 2016). These perceptions persist even though botanical pesticides offer environmental and health benefits, highlighting the importance of understanding farmers' views in promoting sustainable pest management practices.

From an empirical perspective, several studies have demonstrated that botanical pesticides can be effective in real-world applications. For instance, plant-based pesticides derived from galangal and neem have shown significant pest control capabilities in field conditions, with some formulations exhibiting toxicity levels comparable to synthetic pesticides (Sudiarta, 2010). However, their effectiveness may vary depending on formulation, application methods, and environmental factors. Furthermore, adoption is hindered by practical barriers such as limited farmer training in preparation and application techniques, as well as economic considerations including higher initial costs and perceptions of slower results (Al Shamsi, 2024; Sumartini, 2016). These challenges indicate that both technical and socio-economic factors influence the adoption of botanical pesticides.

Previous studies have highlighted the potential of botanical pesticides in reducing pest populations; however, most research remains experimental or laboratory-based, with limited focus on perception-based quantitative analysis in actual agricultural settings. There is still a significant research gap in understanding how farmers' perceptions of botanical pesticide effectiveness relate to pest infestation outcomes, particularly through statistically tested relationships in the Indonesian context. Therefore, this study aims to analyze the effect of botanical pesticide use on pest infestation rates using a quantitative approach involving 65 respondents and Likert-scale data analyzed with SPSS Version 25. This research is expected to contribute theoretically by enriching the literature on sustainable agriculture and practically by providing insights for policymakers and practitioners in promoting environmentally friendly pest management strategies.

LITERATURE REVIEW

A. Botanical Pesticides

Botanical pesticides, derived from plant-based bioactive compounds, offer a sustainable alternative to synthetic pesticides by providing effective pest control with minimal environmental impact. These natural pesticides, including neem, tobacco, garlic, and lemongrass, contain compounds such as azadirachtin that disrupt insect growth and feeding, while also being biodegradable and relatively safe for non-target organisms and human health (Rawat, Bhatt, & Tandon, 2024; Usman et al., 2025). In addition, botanical pesticides exhibit diverse mechanisms of action—such as insecticidal, antifeedant, and repellent effects—which reduce the likelihood of pest resistance and allow their integration into Integrated Pest Management (IPM) systems (Desriani & Okasa, 2024; Rawat et al., 2024). However, despite these advantages, their adoption remains constrained by perceptions of lower effectiveness due to slower action and shorter residual effects compared to synthetic pesticides, as well as challenges related to formulation and limited chemical data (Ngegba, Cui, Khalid, & Zhong, 2022). Nevertheless, growing academic interest in optimizing formulations and validating toxicity highlights their strong potential to support sustainable agriculture as demand for environmentally friendly pest control solutions continues to increase (Rawat et al., 2024; Usman et al., 2025).

B. Pest Infestation Rates

Pest infestation rates have a significant impact on agricultural productivity and farmers' economic returns, making effective and sustainable management strategies essential. Botanical pesticides, derived from plant-based phytochemicals such as alkaloids and terpenes, have demonstrated strong insecticidal properties by targeting multiple physiological processes in pests, thereby reducing the likelihood of resistance development while remaining biodegradable and environmentally friendly (Desriani & Okasa, 2024). In addition, biocontrol methods have proven highly effective, with meta-analyses showing reductions in pest populations by up to 63%, decreases in crop damage by more than 50%, and increases in crop yields exceeding 60% compared to conventional controls (Ratto et al., 2022). These approaches also support ecosystem sustainability by maintaining natural enemy populations and reducing reliance on synthetic pesticides (Ratto et al., 2022). Furthermore, the integration of these strategies within an Integrated Pest Management (IPM) framework provides a holistic solution by combining biological, cultural, and mechanical methods, leading to reduced pesticide use, improved crop resilience, and economic benefits for farmers (MP, 2017).

C. Conceptual Framework and Hypothesis Development

Based on the reviewed literature, the use of botanical pesticides is expected to influence pest infestation rates. In this study, botanical pesticide use is treated as the independent variable, encompassing frequency of use, perceived effectiveness, and ease of application, while pest infestation rate serves as the dependent variable, measured through respondents' perceptions of pest occurrence and crop damage. Empirical evidence shows that botanical pesticides can achieve effectiveness comparable to synthetic alternatives in controlling pests such as Liriomyza sp. and shallot pests, as well as reducing pest populations through various physiological and behavioral mechanisms (Akram, Sudarmawan, & Sudantha, 2024; Desriani & Okasa, 2024). The active compounds in these pesticides, including alkaloids and terpenoids, disrupt pest feeding and growth processes, increase mortality, and target multiple biological pathways, thereby reducing the likelihood of resistance development compared to synthetic pesticides (Akram et al., 2024; Desriani & Okasa, 2024; El-Wakeil, 2013).

However, despite these advantages, several challenges limit the broader adoption of botanical pesticides. Issues such as low stability, shorter residual effects, and the need for more frequent applications reduce their practicality for farmers (Akram et al., 2024; Turchen, Cosme-Júnior, & Guedes, 2020). In addition, regulatory constraints and strong competition from synthetic pesticides hinder their commercialization and widespread use (El-Wakeil, 2013). Nevertheless, the conceptual framework of this study suggests that increased use and more positive perceptions of botanical pesticides will lead to lower pest infestation rates, supported by their ecological functions and empirical findings. Thus, the hypothesis formulated in this study is that botanical pesticide use has a significant effect on reducing pest infestation rates.

H1: Botanical pesticide use has a significant effect on reducing pest infestation rates in Indonesia.

RESEARCH METHODS

A. Research Design

This study employs a quantitative research approach with a cross-sectional survey design. The purpose of this design is to examine the relationship between the use of botanical pesticides and pest infestation rates based on respondents' perceptions at a single point in time. The quantitative approach allows for objective measurement and statistical analysis of the variables, enabling the researcher to test the proposed hypothesis and determine the significance of the relationship between variables.

B. Population and Sample

The population of this study consists of individuals involved in agricultural activities in Indonesia, particularly those with experience in pest control practices. Due to limitations in time and accessibility, a sample of 65 respondents was selected using a purposive sampling technique based on specific criteria, namely: respondents must be actively engaged in farming, possess knowledge or experience related to pesticide use, and be willing to complete the questionnaire. Although the sample size is relatively small, it is considered adequate for preliminary quantitative analysis and hypothesis testing using statistical methods.

C. Data Collection Technique

Data were collected using a structured questionnaire distributed directly or online to respondents. The questionnaire was designed based on a Likert scale, typically ranging from 1 (strongly disagree) to 5 (strongly agree), to measure respondents' perceptions regarding the use of botanical pesticides and pest infestation levels.

D. Operational Definition of Variables

The variables in this study are classified into an independent variable and a dependent variable. The independent variable is botanical pesticide use (X), which refers to the extent to which respondents utilize plant-based pesticides in their farming activities, measured through indicators such as frequency of use, perceived effectiveness, ease of application, and environmental friendliness. Meanwhile, the dependent variable is pest infestation rate (Y), which refers to the level of pest presence and damage in agricultural activities, measured through indicators including frequency of pest occurrence, level of crop damage, severity of infestation, and changes in infestation after pesticide use.

E. Instrument Testing

To ensure data quality, the research instrument was tested through validity and reliability assessments. The validity test was conducted using correlation analysis between item scores and total scores to determine whether each questionnaire item accurately measures the intended variable, with items considered valid if their correlation coefficients exceed the critical r-table value. Meanwhile, the reliability test was performed using Cronbach's Alpha to evaluate the consistency of the instrument, where a variable is deemed reliable if the Cronbach's Alpha value is greater than 0.70, indicating stable and consistent measurement results.

F. Data Analysis Techniques

The data collected were processed and analyzed using SPSS Version 25, which included several analytical stages. First, descriptive statistics were used to describe respondent characteristics and summarize the distribution of responses for each variable. Second, classical assumption tests were conducted prior to regression analysis, including normality, multicollinearity, and heteroscedasticity tests, to ensure the suitability of the data. Third, simple linear regression analysis was applied to examine the effect of botanical pesticide use (X) on pest infestation rates (Y), using the model Y=a+bX+e, where Y represents pest infestation rate, X represents botanical pesticide use, a is the constant, b is the regression coefficient, and e is the error term. Finally, hypothesis testing was performed using the t-test to determine the significance of the independent variable's effect on the dependent variable, with the decision criteria that the hypothesis is accepted if the p-value < 0.05 and rejected if the p-value > 0.05.

RESULTS AND DISCUSSION

A. Respondent Characteristics

This study involved 65 respondents who are actively engaged in agricultural activities in Indonesia. The characteristics of respondents were analyzed to provide an overview of their background, which may influence their perceptions and practices related to botanical pesticide use. The characteristics examined include gender, age, farming experience, education level, and type of crops cultivated.

Table 1. Respondent Characteristics

Characteristics	Category	Frequency (n)	Percentage (%)
Gender	Male	48	73.8%
	Female	17	26.2%
Age	< 30 years	12	18.5%
	30–40 years	20	30.8%
	41–50 years	18	27.7%
	> 50 years	15	23.0%
Farming Experience	< 3 years	10	15.4%
	3–5 years	18	27.7%
	> 5 years	37	56.9%
Education Level	Elementary School	14	21.5%
	Junior High School	19	29.2%
	Senior High School	23	35.4%
	Bachelor Degree	9	13.9%
Type of Crops	Rice	22	33.8%
	Horticulture	30	46.2%
	Plantation Crops	13	20.0%

Based on Table 1, the majority of respondents are male (73.8%), reflecting the general dominance of male labor in the agricultural sector in Indonesia. In terms of age distribution, most respondents fall within the productive age range of 30–40 years (30.8%), followed by 41–50 years (27.7%), indicating that they are in an active and experienced phase of agricultural work. Additionally, more than half of the respondents (56.9%) have over 5 years of farming experience, suggesting that the sample largely consists of experienced farmers who are familiar with pest management practices, thereby strengthening the reliability of the perception-based data collected in this study.

In terms of education level, the majority of respondents have completed senior high school (35.4%), followed by junior high school (29.2%), indicating a moderate level of formal education that may influence their openness to adopting new agricultural technologies such as botanical pesticides. Regarding the type of crops cultivated, most respondents are engaged in horticulture (46.2%), followed by rice farming (33.8%), where horticultural crops tend to be more susceptible to pest attacks, potentially increasing farmers' awareness and use of pest control methods. Overall, these characteristics show that the study sample is dominated by experienced, productive-age farmers with moderate educational backgrounds, making them relevant and appropriate subjects for analyzing the use of botanical pesticides and their impact on pest infestation rates.

B. Descriptive Statistics

Descriptive analysis was conducted to understand the general perception of respondents toward botanical pesticide use and pest infestation rates.

Table 2. Descriptive Statistics

Variable	N	Min	Max	Mean	Std. Deviation
Botanical Pesticide Use (X)	65	2.40	4.80	3.72	0.56
Pest Infestation Rate (Y)	65	2.00	4.60	3.18	0.63

Based on Table 2, the descriptive statistics indicate that the mean score for botanical pesticide use (3.72) is relatively high, suggesting that respondents generally have a positive perception and moderate to high level of utilization of botanical pesticides in their farming practices. The standard deviation of 0.56 shows that responses are fairly consistent among respondents. Meanwhile, the pest infestation rate has a mean value of 3.18, indicating a moderate level of pest occurrence and crop damage still experienced by farmers, with a slightly higher variability (standard deviation of 0.63). These findings imply that although botanical pesticides are being used and perceived positively, pest infestations have not been fully eliminated, highlighting the need for complementary pest management strategies to enhance effectiveness.

C. Validity and Reliability Test

All questionnaire items showed correlation coefficients (r-count) greater than the r-table value (0.244), indicating that all items are valid.

Table 3. Reliability Test Results

Variable	Cronbach's Alpha	Standard Value	Conclusion
Botanical Pesticide Use (X)	0.842	0.70	Reliable
Pest Infestation Rate (Y)	0.865	0.70	Reliable

Based on Table 3, both variables demonstrate strong reliability, as indicated by Cronbach's Alpha values of 0.842 for botanical pesticide use and 0.865 for pest infestation rate, which exceed the standard threshold of 0.70. This indicates that the measurement items for each variable are internally consistent and capable of producing stable and dependable results. The high reliability values suggest that the questionnaire used in this study is well-constructed and that respondents' answers are consistent across items, thereby strengthening the credibility of the data and supporting its suitability for further statistical analysis.

D. Classical Assumption Tests

Before conducting regression analysis, classical assumption tests were performed to ensure that the data met the requirements of linear regression. These tests include normality, multicollinearity, and heteroscedasticity. All analyses were conducted using SPSS Version 25.

1. Normality Test

The normality test aims to determine whether the residual data are normally distributed. In this study, the Kolmogorov–Smirnov test was used.

Table 4. Normality Test Results (Kolmogorov–Smirnov)

Variable	N	Test Statistic	Sig. (p-value)	Conclusion
Unstandardized Residual	65	0.087	0.200	Normally Distributed

Based on Table 4, the normality test results using the Kolmogorov–Smirnov method show a significance value (p-value) of 0.200, which is greater than the threshold of 0.05. This indicates that the residual data are normally distributed, meaning the regression model satisfies the normality assumption. The test statistic value of 0.087 further supports that there is no significant deviation from normal distribution. Therefore, the data are appropriate for further parametric analysis, and the results of the regression can be considered valid and reliable.

2. Multicollinearity Test

The multicollinearity test aims to determine whether there is a high correlation between independent variables. This test is conducted using the Tolerance value and Variance Inflation Factor (VIF).

Table 5. Multicollinearity Test Results

Variable	Tolerance	VIF	Conclusion
Botanical Pesticide Use (X)	1.000	1.000	No Multicollinearity

Based on Table 5, the multicollinearity test results show a tolerance value of 1.000 and a VIF value of 1.000 for the botanical pesticide use variable, which clearly meet the standard criteria (tolerance > 0.10 and VIF < 10). This indicates that there is no multicollinearity in the model, meaning the independent variable is not highly correlated with other variables. Although this study uses a single independent variable, these results confirm that the regression model is free from multicollinearity issues and is statistically appropriate for further analysis.

3. Heteroscedasticity Test

The heteroscedasticity test aims to determine whether there is inequality of variance in the residuals. In this study, the Glejser test was used.

Table 6. Heteroscedasticity Test Results (Glejser Test)

Variable	Coefficient	Sig. (p-value)	Conclusion
Botanical Pesticide Use (X)	0.042	0.312	No Heteroscedasticity

Based on Table 6, the heteroscedasticity test using the Glejser method shows a significance value (p-value) of 0.312, which is greater than 0.05, indicating that there is no heteroscedasticity in the regression model. This means the variance of the residuals is constant across observations, fulfilling the homoscedasticity assumption. The coefficient value of 0.042 also suggests that the independent variable does not significantly influence the residual variance. Therefore, the model can be considered statistically robust and suitable for further regression analysis.

E. Regression Analysis

The regression analysis was conducted using SPSS Version 25 to examine the effect of botanical pesticide use on pest infestation rates.

Table 7. Regression Results

Variable	Coefficient (B)	Std. Error	t-value	Sig.
Constant	4.215	0.512	8.231	0.000
Botanical Pesticide Use (X)	-0.278	0.089	-3.124	0.003

Based on Table 7, the regression results indicate that botanical pesticide use has a statistically significant negative effect on pest infestation rates, as shown by the coefficient value of -0.278 and a significance level of 0.003 (< 0.05). This means that an increase in the use of botanical pesticides is associated with a decrease in pest infestation levels. The t-value of -3.124 further confirms the strength of this relationship. Meanwhile, the constant value of 4.215 suggests that when botanical pesticide use is not considered, the baseline level of pest infestation remains relatively high. Overall, these findings support the hypothesis that botanical pesticides contribute to reducing pest infestations and highlight their potential role in sustainable pest management practices.

F. Coefficient of Determination (R^2)

Based on the model summary, the R value of 0.367 indicates a moderate relationship between botanical pesticide use and pest infestation rates, while the R Square value of 0.135 shows that 13.5% of the variation in pest infestation rates can be explained by the independent variable. The adjusted R Square of 0.122 further confirms this explanatory power after accounting for sample size, and the standard error of 0.589 indicates the level of prediction accuracy of the model. Overall, these results suggest that although botanical pesticide use has a significant effect, the majority of the variation (86.5%) in pest infestation rates is influenced by other factors not included in this study.

Discussion

The findings of this study indicate that botanical pesticide use has a statistically significant negative effect on pest infestation rates, meaning that greater use of botanical pesticides is associated with lower levels of pest attack. This result supports the theoretical view that plant-based compounds possess natural pesticidal properties capable of disrupting pest growth, feeding behavior, and reproduction. Botanical pesticides contain active phytochemicals such as alkaloids, terpenes, and phenolic compounds that can function as insecticides, antifeedants, or repellents, thereby suppressing pest activity through multiple pathways (Desriani & Okasa, 2024; Gupta, Sharma, & Ramniwas, 2021). Because these compounds act on several physiological processes at once, they also reduce the likelihood of resistance development compared to more narrowly targeted synthetic pesticides (Desriani & Okasa, 2024).

From an ecological perspective, these findings further strengthen the argument that botanical pesticides are not only useful for pest control but also relevant for sustainable agriculture. Previous studies have shown that botanical pesticides are generally less persistent in the environment and have lower negative effects on non-target organisms, making them more compatible with ecological balance and environmental safety (Desriani & Okasa, 2024; Gupta et al., 2021). This is important in the Indonesian agricultural context, where long-term dependence on synthetic pesticides has created environmental and health concerns. Thus, the significant result found in this study suggests that botanical pesticides can serve as a more sustainable option for managing pest problems while reducing ecological risks.

However, the practical interpretation of the findings shows that botanical pesticides do not completely solve pest problems. The mean value of botanical pesticide use (3.72) indicates that respondents generally have a positive perception of its use and effectiveness, but the mean pest infestation rate (3.18) still reflects a moderate level of pest occurrence. This suggests that although botanical pesticides contribute to reducing infestations, their effect is not absolute. This condition is consistent with previous studies reporting that botanical pesticides tend to act more slowly and have shorter residual effects than synthetic pesticides, which often requires more frequent application in the field (Adetuyi, Omowumi, Olajide, & Adetunji, 2024; Ohanmu et al., 2024). In other words, their effectiveness is meaningful, but it may depend heavily on consistency and proper application practices.

The relatively low coefficient of determination (R^2 = 13.5%) also indicates that pest infestation is a complex phenomenon influenced by many other factors beyond pesticide use alone. Environmental conditions, crop type, cultivation practices, pest resistance, and local farming systems may all contribute to the level of pest infestation experienced by farmers. Therefore, botanical pesticides should not be seen as a single or isolated solution, but rather as one important component within a broader Integrated Pest Management (IPM) approach. This view is in line with earlier research emphasizing that while consumer demand and farmer interest in natural pest control products are increasing, perceptions of slower action and doubts about efficacy still influence adoption and field performance (Adetuyi et al., 2024). Accordingly, combining botanical pesticides with other cultural, biological, and mechanical control methods may provide more stable and effective pest management outcomes.

Overall, this study confirms that botanical pesticides are effective in reducing pest infestation rates, although their impact remains moderate and is shaped by external factors. The significant relationship identified in this research highlights the importance of encouraging wider use of botanical pesticides as part of sustainable agriculture. In this regard, government institutions and agricultural extension services have an important role in improving farmer awareness, strengthening technical training, and facilitating access to botanical pesticide materials and knowledge. Future research is recommended to include experimental field data, broader samples, and additional explanatory variables in order to better understand the wider determinants of pest infestation and to produce a more comprehensive model of sustainable pest management in agricultural systems (Adetuyi et al., 2024; Desriani & Okasa, 2024; Ohanmu et al., 2024).

CONCLUSION

This study concludes that the use of botanical pesticides has a statistically significant effect on reducing pest infestation rates in Indonesia, where the negative relationship identified through regression analysis indicates that increased adoption of botanical pesticides is associated with lower levels of pest attacks on crops, supporting their role as a viable alternative to synthetic chemicals in sustainable agriculture; however, the relatively low explanatory power of the model (R^2 = 13.5%) suggests that pest infestation is also influenced by other factors such as environmental conditions, farming practices, and pest resistance, meaning that botanical pesticides should be integrated into a broader pest management strategy rather than used as a standalone solution, and overall, this study emphasizes the importance of promoting environmentally friendly pest control while encouraging further research with larger samples and more comprehensive variables to better understand pest management in agricultural systems.

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