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Factors Influencing the Adoption of Integrated Pest Control Technology (T- PHT) in Tobacco Cultivation in Pamekasan Regency

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Abstract
The tobacco sector has a strategic role in the Indonesian economy, including in Pamekasan Regency, as a producer of aromatic tobacco. However, cultivation practices that still rely on chemical pesticides harm the environment and health. Integrated Pest Control (PHT) was introduced as a sustainable solution, but the adoption rate is still low. This study aims to analyze the factors that affect the adoption of PHT Technology (T-PHT) in tobacco cultivation in Pamekasan. The study used a mixed-methods approach with a census sample of 50 farmers from two central sub-districts. Data were collected through questionnaires, interviews, and observations, and then analyzed descriptively and inferentially by multiple linear regression. The results of the study identified barriers to adoption that are multidimensional, including technical, economic, socio-cultural, institutional, and external aspects. The characteristics of farmers are dominated by productive age (35–54 years), farming experience of more than 10 years, lower middle education, and small land ownership (<2 hectares). The regression results showed that simultaneously, age, education, experience, land area, and counseling factors had a significant effect on the adoption of T-PHT ($F=18.147$; $p<0.05$). Partially, the quality of extension was the dominant factor ($\beta=0.368$; $p=0.002$), followed by age ($\beta=0.364$; $p=0.004$) and farming experience ($\beta=0.240$; $p=0.048$). Formal education and land area have no significant effect. The regression model explains 63.6% of the variation in adoption. It was concluded that increasing the adoption of T-PHT requires an intensive, participatory, and contextual extension approach, utilizing the experience and local wisdom of farmers. Policy implications are directed at strengthening extension programs, ongoing mentoring, and support that reduces the perception of smallholder economic risks.

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1. Introduction

The tobacco sector plays a strategic role in Indonesia's economic structure, not only as a provider of employment and a source of income for millions of farming households, but also as a significant contributor to state revenue through the Tobacco Products Excise (CHT). In 2023, CHT's contribution will reach IDR 286.19 trillion, which accounts for 75.59% of the total revenue of Customs and Excise (Ministry of Finance, 2024) [7]. This large financial contribution is inseparable from the role of tobacco production centers in various regions, one of which is Pamekasan Regency on Madura Island. As a producer of quality aromatic tobacco, Pamekasan has a planting area of 31,183.20 hectares with a production of 28,296.70 tons in 2024 (BPS, 2025). This commodity is the backbone of the local economy, especially in the dry season.

However, behind its economic potential, tobacco cultivation faces serious sustainability challenges. Conventional practices that are still dominant are characterized by a high dependence on synthetic chemical inputs, such as fertilizers and pesticides. The intensive and often unwise use of chemical pesticides has led to multidimensional negative impacts, including decreased soil fertility, environmental pollution, pest resistance, farmer health disorders, and residues on products. Furthermore, the demands of the global market and consumer awareness of environmentally friendly products increasingly urge the need for a transformation towards a more sustainable agricultural system.

In response to these challenges, the concept of Integrated Pest Management (IPM) was introduced as an ecological, economical, and sustainable OPT management approach. PHT integrates various control methods, such as technical, physical/mechanical, biological, and selective chemical pesticide culture as the last option, with the basic principles of agroecosystem monitoring and empowerment of farmers as decision-makers. In Pamekasan Regency, efforts to disseminate PHT Technology (T-PHT) have been carried out by the Food Security and Agriculture Service (DKPP) through field school and counseling programs.

However, the reality on the ground shows that the rate of T-PHT adoption by tobacco farmers is still relatively low. Many farmers still view chemical pesticides as a faster, more practical, and more effective solution compared to PHT methods, which are considered complicated, time-consuming, and the results are less immediately visible. This gap between technology introduction efforts and adoption rates indicates a complex of barriers and determinants that have not been fully identified and resolved. Preliminary and observational studies show that farmers' adoption decisions are thought to be influenced by the interaction of internal factors (such as demographic and socio-economic characteristics) and external factors (such as the quality of extension and institutional conditions).

Based on this background, this study was conducted to comprehensively examine the problem of low adoption of T-PHT in tobacco center areas. This study specifically aims to analyze the influence of farmer characteristics factors (age, education, experience, land area) and extension activities on the adoption rate of T-PHT.

The findings of this research are expected not only to make an academic contribution in enriching the treasure of agricultural innovation diffusion science, especially in high-value plantation commodities, but also to provide significant practical implications. For stakeholders, especially local governments and agricultural extension workers, the results of the research can serve as an empirical basis in formulating policies, designing more effective and contextual extension programs, and developing targeted intervention strategies to accelerate the adoption of sustainable agricultural practices, which ultimately support increased productivity, environmental sustainability, and welfare of tobacco farmers in Pamekasan Regency.

2. Research Methodology

This study uses a descriptive-analytical approach with a mixed-methods sequential explanatory design. The location of the research was deliberately determined in Pamekasan and Tlanakan Districts, Pamekasan Regency, in the June-August 2025 period. The study population is active tobacco farmers in the two sub-districts. Given the limited and homogeneous population size, the sampling technique was conducted by census, with 50 farmers as respondents.

Data were collected through structured questionnaires (using a Likert scale of 1-5), in-depth interviews, field observations, and document studies. The questionnaire and interviews were designed to measure dependent variables, namely the Adoption Rate of T-PHT (Y), as well as independent variables, which included Age (X_1), Education (X_2), Farming Experience (X_3), Land Area (X_4), and Quality of Extension (X_5).

Data analysis is carried out in stages. First, descriptive analysis is used to identify barriers and profile respondents. Second, an inferential analysis with multiple linear regression was performed to test the influence of independent variables on the adoption of T-PHT. Before the regression analysis, validity, reliability, and classical assumption tests (normality, multicollinearity, and heteroscedasticity) were carried out, all of which were satisfactory. Data processing is assisted by SPSS software version 22.

3. Results And Discussion

3.1. Characteristics of Farmers

Farmer characteristics are an important factor in understanding how farmers assess and respond to agricultural innovation. The results of the study show that most tobacco farmers in Pamekasan Regency are of productive age and have relatively long farming experience. This experience shapes the cautious attitude of farmers in accepting new technologies, especially those related to pest control.

Table 1: Characteristics of farmers

Farmer Age (Year)	Number (People)	Education	Number (People)	Farming Experience (Year)	Number (People)	Land Area (Ha)	Number (People)
25	4	No School	4	<5	5	< 0.5	7
25–34	11	SD	11	5–10	10	0,5–1	18
35–44	18	SMP	23	11–15	21	1,1–2	13
45–54	14	SMA	10	16–20	11	2,1–3	10
>55	3	College	2	>20	3	> 3	2

Table 1 provides an in-depth overview of the socio-demographic and economic profiles of 50 respondent farmers in Pamekasan and Tlanakan Districts, Pamekasan Regency. This profile is a crucial contextual foundation for analyzing research findings regarding the adoption of Integrated Pest Control Technology (T-PHT).

Most of the respondents (64%) were in the productive to mature age group (35-54 years). The 35-44 age group is the highest proportion (36%), followed by the 45-54 year old group (28%). Only 8% are under the age of 25, and 6% are over 55. The dominance of farmers in this middle- aged group indicates that the tobacco farming sector is dominated by individuals with a high level of maturity and stability. The results of the regression analysis showing the positive and

significant influence of age variables on the adoption of T-PHT can be found here. Age maturity often correlates with more holistic and long-term-oriented considerations, so farmers are more open to evaluating and adopting sustainable farming practices, even if it requires adaptation from conventional habits.

At the education level, the majority of respondents (88%) have an educational background at the high school level and below. As many as 46% have a high school education, 22% elementary school education, and 20% high school education. Only 4% have higher education, while 8% have never attended formal education. This configuration reflects a relatively low level of formal education, which is a common characteristic of the traditional agricultural sector. These findings provide a basis for understanding why the results of the regression analysis show that formal education does not have a significant effect on the adoption of T-PHT. The implication is that the transfer of innovation and behavior change in this context is more effectively driven through communication and non-formal learning channels, such as practical counseling, field demonstrations, and peer-to-peer learning, rather than relying on formal education levels.

In the characteristics of farmers in terms of farming experience, most respondents (64%) have more than 10 years of tobacco farming experience, with the largest proportion in the 11-15 years category (42%). Only 10% have less than 5 years of experience. The high accumulation of this experience shows that tobacco cultivation in the study area is generally carried on for generations and has been the main source of livelihood for a long time. These findings are in line with the results of regression analysis that confirm the significant positive influence of farming experience variables. The reservoir of local knowledge and intuitive understanding of the dynamics of agroecosystems owned by experienced farmers are valuable asset to understand the ecological logic behind PHT principles.

For the characteristics of the land area, the land ownership structure shows the characteristics of small and medium farmers. As many as 36% of respondents manage an area of 0.5-1 hectare, and 26% manage 1.1-2 hectares. Thus, the majority of farmers (62%) are smallholders with less than 2 hectares of land. Only 4% cultivate land above 3 hectares. This profile corroborates the findings of the regression analysis that land area does not have a significant effect on the adoption of T-PHT. PHT technology is scale-neutral and can be applied to various business scales. However, for smallholder farmers, high management intensity and heavy reliance on crops can create economic vulnerabilities that make them more cautious and less resilient to the risk of experimenting with new methods. Therefore, counseling and support approaches need to be sensitive to the context of these vulnerabilities.

Overall, the profile of the study respondents was dominated by experienced, mature, lower- middle-educated farmers, and small-scale landowners. This configuration of characteristics creates a unique socio-economic context, where local wisdom and practical learning are of very high value. These findings reinforce the recommendation that efforts to disseminate and increase the adoption of T-PHT should prioritize a participatory, contextual, and demonstration-based approach to counseling and be supported by policies that can reduce the perception of economic risk for smallholders.

3.2. Factors Affecting the Adoption Rate of T-PHT

Statistical analysis was conducted to test the influence of farmer characteristics and extension factors on the adoption rate of Integrated Pest Control Technology (T-PHT). Before the regression analysis, a classical assumption test was carried out, which showed that the data met the requirements of normality ($p > 0.05$ in the Kolmogorov-Smirnov test), were free from multicollinearity (VIF value < 10 and Tolerance > 0.10), and did not experience heteroscedasticity based on residual plots. This ensures the reliability of the regression model built.

1. Analysis of factors influencing the simultaneous adoption of T-PHT

Multiple linear regression analysis yields statistically significant models. The results of the simultaneous test (F-test) are presented in Table 2, which shows that the five independent variables together have a significant effect on the rate of T-PHT adoption.

Table 2: Simultaneous influence of factors influencing the adoption of T-PHT

Model	Sum of Squares	df	Mean Square	F	Say
Regression	6027.194	5	1205.439	18.147	.000b
Residual	2922.806	44	66.427		
Total	8950.000	49			

From Table 2. obtained a value of F calculated 18.147 > F table 2.427. Based on the results of the analysis, it can be concluded that the characteristics of farmers and extension activities have a simultaneous effect on the adoption of pht in tobacco cultivation. This shows that to change the habits of farmers from those who usually control pests and diseases in the cultivation process of tobacco plants using chemicals to pest and disease control with T-PHT, not only does the bus rely on one of the factors. Farmer characteristics determine the level of openness of farmers to the existence of new technologies, but these factors must be supported by intensive assistance and information facilities through extension programs. The implementation of T-PHT will be more optimal if farmers have a good knowledge base and are supported by an extension process that matches the characteristics of their farmers.

This result is strengthened by the theory of innovation diffusion by Rogers (2003) [10], which states that the adoption of innovation by farmers is strongly influenced by the characteristics of individual farmers. Farmers who have more progressive characteristics tend to have a better ability to adopt new technologies such as PHT.

An adjusted R^2 coefficient of determination (R^2) of 0.636 revealed that this regression model was able to explain 63.6% variation in T-PHT adoption rates. The remaining 36.4% were influenced by other factors not included in the model, such as psychological factors (risk perception, attitudes, subjective norms), access to financial resources, or more

macro policy variables. These findings are consistent with the research of Dondo *et al*. (2016) [4] and Rahmasari *et al*. (2020) [9] who also found that the adoption of agricultural innovation is the result of a complex interaction of various factors, both internal and external.

2. Analysis of factors influencing the simultaneous adoption of T-PHT

To find out the specific contribution of each variable, a partial test (t-test) was performed.

The complete results of the partial regression analysis are presented in Table 3.

Table 3: Partial influence of factors influencing the adoption of T-PHT

Model	Unstandardized Coefficients		Standardized Coefficients	t	Say	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	Live
(Constant) Age Education Experience Land Counseling	-17.103	5.917		-2.891	.006		
	.491	.162	.364	3.031	.004	.514	1.946
	.374	.413	.097	.906	.370	.650	1.539
	.500	.246	.240	2.029	.048	.531	1.882
	-.674	1.549	-.045	-.435	.666	.699	1.430
	1.795	.556	.368	3.229	.002	.573	1.746

The results of the partial test (t-test) revealed the specific contribution and statistical significance of each independent variable to the adoption rate of Integrated Pest Control Technology (T-PHT). Of the five variables tested, three of them were shown to have a significant effect with different relationship directions, while the other two variables showed no statistically significant influence. An in-depth interpretation of these results provides a clearer picture of the decision-making mechanism for adoption at the farmer level.

First, the variable Quality of Counseling (X_5) emerged as the most dominant factor with the highest regression coefficient (B = 1.795) and very strong significance (p = 0.002). The magnitude of this coefficient suggests that every one-unit increase in the quality of counseling—which includes material relevance, method effectiveness, and mentoring intensity—will increase the T-PHT adoption rate by 1,795 units, assuming other variables are constant. These findings unequivocally confirm the central role of extension as a key catalyst in the process of diffusion of complex agricultural innovations such as PHT. Quality counseling serves as a bridge that overcomes technical and cognitive barriers by transforming abstract knowledge into applicable skills, while building farmers' self-efficacy through direct mentoring. These results are consistent with the research of Anang *et al*. (2020) [1], who found that the intensity and quality of extension are the strongest predictors of the adoption of environmentally friendly technology, and strengthen the argument of Mardikanto (2013) about the importance of participatory extension approaches in changing agricultural behavior. Second, the variables Age (X_1) and Farming Experience (X_3) showed a significant positive influence, although with a lower magnitude than extension. An age coefficient of

0.491 (p = 0.004) indicates that more mature farmers tend to have higher adoption rates. This can be interpreted through the lens of experiential capital accumulation—older farmers have witnessed the long-term impact of conventional farming practices, making them more open to sustainable alternatives. Meanwhile, the farming experience coefficient of 0.500 (p = 0.048) reflects the value of accumulated indigenous knowledge. Experienced farmers have a practical knowledge base about agroecosystem dynamics that makes it easy for them to understand the ecological logic behind the principles of PHT and adapt them to local specific conditions.

These findings are in line with the research of Ismilaili *et al*. (2015), which confirms the positive correlation between experience and adoption of agricultural innovations, as well as supporting the concept of absorptive capacity (Cohen & Levinthal, 1990) [3], which emphasizes that prior knowledge accelerates the assimilation of new knowledge.

Third, the variables of Formal Education (X_2) and Land Area (X_4) did not show a significant influence on the adoption of T-PHT. The insignificance of formal education (p = 0.370) reveals an important reality: in the context of the adoption of practical and locally- specific technologies such as PHT, knowledge gained through non-formal channels—such as experiential learning, interaction with fellow farmers, and field counseling—has a stronger explanatory power than formal education at the school level. These findings are consistent with the research of Rusli Burhansyah (2014) [11], who also found that formal education is not always the main predictor of the adoption of agricultural innovation in traditional communities. Meanwhile, the insignificance of land area (p = 0.666), even with a weak negative coefficient (-0.674), indicates that T-PHT is a scale-neutral and inclusive technology—it can be adopted by both smallholder farmers (who were dominant in the sample) and large areas. This reinforces the findings of Farisa *et al*. (2020) [5] and dismisses the assumption that the adoption of sustainable technology is only feasible for large-scale farming. Overall, this pattern of partial regression results constructs a coherent narrative: T-PHT adoption is primarily driven by quality external interventions (extension), which are then moderated by local knowledge capital that manifests in the form of maturity and accumulated farming experience. Formal education and land tenure structures are not the main barriers, suggesting that the potential for adoption is actually evenly distributed across the socio- economic strata of farmers. The policy implication that emerges is the need to design extension programs that are specifically designed to empower the experiential capital of mature and experienced farmers, with materials and methods that translate the scientific

principles of PHT into the local knowledge framework they already have.

4. Conclusion

Based on the results of the study, it can be concluded that the adoption of Integrated Pest Control Technology (T-PHT) in tobacco cultivation in Pamekasan Regency is still low due to interrelated multidimensional obstacles, including technical, economic, socio-cultural, institutional, and external aspects. The profile of farmers is dominated by productive age, long

farming experience, lower secondary education, and small-scale land ownership, which forms a cautious attitude towards innovation. The results of multiple linear regression analysis showed that the quality of extension was the dominant factor that had a positive and significant effect on the adoption rate, followed by age and farming experience. Meanwhile, formal education and land area did not have a significant effect, indicating that T-PHT is scale-neutral and can be adopted by various strata of farmers. The regression model built was able to explain 63.6% of the variation in adoption, with the rest influenced by factors outside the model, such as psychological, financial, and macro policies. Implicitly, efforts to increase the adoption of T-PHT require an intensive, participatory, and contextual extension approach, designed to empower farmers' local knowledge capital, as well as supported by policies that reduce the perception of economic risks, especially for smallholders. Thus, the transformation towards a sustainable tobacco farming system in Pamekasan Regency can be accelerated to support productivity, environmental sustainability, and farmers' welfare.

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