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Adoption of Sex Pheromones in *Spodoptera exigua* Control in the Covid-19 Pandemic Era: Study Case of Tarogong Kaler Garut, Indonesia

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Abstract One of the reasons for the decline in shallot productivity is the attack of onion caterpillar pests (*Spodoptera exigua*), which can cause up to 100% yield loss. The present study responds to these problems with the objectives of 1) describing the level of sex pheromone adoption in onion caterpillar control, 2) analyzing the factors influencing adoption, and 3) formulating a strategy to increase the adoption of sex pheromone technology. The study was carried out for 3 months (March - June 2022) in Tarogong Kaler District, Garut, Indonesia with a population of 127 farmers. The determination of the sample used the Slovin formula with a gallate of 10%, leading to a sample of 60 people. The approach used is in the form of quantitative research supported by qualitative data. Data analysis used descriptive and multiple linear regression analysis with Covid-19 as a dummy variable. The study results showed that most of the respondents (65%) stated that adopting sex pheromones was in the moderate category. Factors influencing adoption are learning class, production unit, compatibility, trialability, observability, and extension activities. The strategy to increase adoption is carried out by maximizing the factors that influence adoption, one of which is through extension activities related to sex pheromone technology material, group administration, information sources, and presentation of the results of pilot plots which are strengthened by extension methods and media.

Keywords Farmer Adoption, Sex Pheromones, Onion Caterpillar (*Spodoptera exigua*)

1. Introduction

The role of agricultural extension workers is closely related to adopting innovation, and its application is interconnected with the implementation of extension services [1]. The problem faced during the COVID-19 pandemic era was the existence of large-scale social restrictions, which impacted limited agricultural extension activities. Wibowo [2] states that one of the problems of the COVID-19 pandemic is farmer's low cosmopolitan level, so information is slow to obtain. This issue presents a challenge in the agricultural extension field which can potentially reduce technology adoption.

Tarogong Kaler is a District in Garut Regency that cultivates shallots. The productivity of shallots in Tarogong Kaler District has only reached 8.3 tonnes/ha, and this result is still low compared to the average shallot productivity in Garut Regency, which reaches 9.67 tonnes/ha [3]. Resmayeti and Samudra [4] state that one of the reasons for the decreased productivity of shallots is due to attacks by onion caterpillar pests (*Spodoptera exigua*). Onion caterpillar attacks can cause yield losses of up to 100% if no control measures are taken [5].

Based on data from the Tarogong Kaler District Program for 2022, around 50% of farmers use excessive doses of chemical pesticides to control pests and diseases [6]. The negative impact of the continuous use of chemical pesticides causes residues in crops and processed materials, as well as environmental pollution, which impacts ecosystem instability [7]. So, it is necessary to apply appropriate and environmentally friendly technology, including sex pheromone technology. Referring to these problems, it is essential to study the adoption of sex pheromone technology in controlling onion caterpillar pests during the COVID-19 pandemic era. In a previous study, Grozea and Costea [8] mention that the capacity capture of pheromone traps in corn was about 72.68%, making pheromones effective in controlling pests.

Research objectives: (1) to describe the level of adoption of sex pheromone technology in controlling onion caterpillar pests during the COVID-19 pandemic era in Tarogong Kaler District; (2) analyze the factors influencing adoption of sex pheromone technology in controlling onion caterpillar pests during the COVID-19 pandemic era in Tarogong Kaler District; (3) Formulate a strategy to increase the adoption of sex pheromone technology in controlling onion caterpillar pests during the COVID-19 pandemic era in Tarogong Kaler District**.**

Research Thinking Framework

The framework for this study refers to [9], with variables such as the function of farmer groups (X_1) with sub-variables including learning class ($X_{1.1}$), vehicle for cooperation ($X_{1.2}$) and production units ($X_{1.3}$). Research by [4] had the following variables: innovation attributes (X_2) with sub-variables including relative advantage ($X_{2.1}$), compatibility ($X_{2.2}$), complexity ($X_{2.3}$), triability ($X_{2.4}$), and observability ($X_{2.5}$); research by [10] with the variables taken are external factors (X_3) with sub-variables including extension activities ($X_{3.1}$), sources of information ($X_{3.2}$), and facilities and infrastructure ($X_{3.3}$); and the COVID-19 pandemic as a dummy variable. While the level of adoption (Y) of sex pheromone technology in controlling onion caterpillar pests consists of knowledge ($Y_{1.1}$), persuasion ($Y_{1.2}$), decision ($Y_{1.3}$), implementation ($Y_{1.4}$), and confirmation ($Y_{1.5}$) refers to [11]. Schematically, the framework is presented in Figure 1.

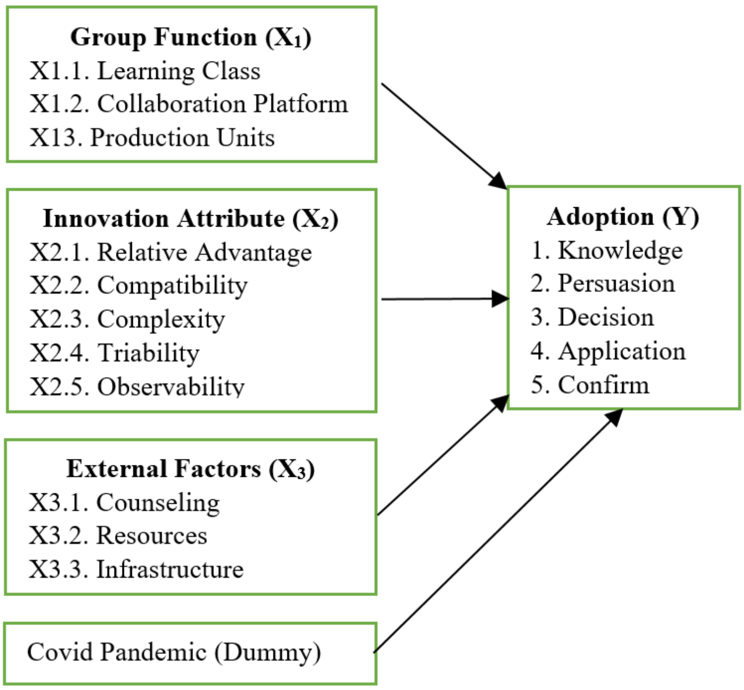

Figure 1. Framework for adopting sex pheromone technology

2. Research Methods

The final project activity was carried out for 3 months, from March to June 2022, in Tarogong Kaler District, with the study area covering Ranjuango, Sukawangi, and Panjiwangi Villages. The total population of 127 people was determined through the purposive sampling method. The population criteria determined in this study are members of farmer groups who cultivate shallots that are recommended by local extension workers. Determination of the sample using the Slovin formula with an error of 10%, to obtain a total sample of 55.9, approaching up to 60 samples.

The data used in this study came from primary data and secondary data obtained through observation, interviews, questionnaires, and reviewing references. The validity test was conducted by testing the instrument on 26 farmers with the same characteristics as the respondents. Then, the r count > r table is obtained with an r table value of 0.404. Thus, 37 questions are declared valid out of a total of 46 questions, and repairs are made for 9 questions that are not valid. Testing the instrument's reliability was conducted by comparing the Cronbach alpha value [12], which obtained a reliability value of 0.943> 0.60, meaning that the questionnaire was declared reliable.

Data analysis used is descriptive analysis and multiple linear regression with dummy variables. The adoption rate of farmers in applying sex pheromone technology was analyzed using descriptive analysis divided into three categories: namely low, moderate, and high. Multiple linear regression analysis with a dummy variable is used to determine how much influence the sub-variables have on the dependent variable of farmer adoption (Y). In regression analysis, several assumptions must be met to validate the resulting regression equation when used to predict. Ghozali [13] states that the classical assumption tests include tests for normality, multicollinearity, heteroscedasticity, and autocorrelation tests.

3. Results

3.1. Variable Description

Based on the descriptive analysis of the research variables, the performance of the variables, in general, was included in the moderate category. It is presented in detail in Table 1.

Table 1 shows the results of a descriptive analysis of 69.17% of farmers assessing the function of farmer groups in adopting sex pheromone technology in the moderate category, with 42 farmers as respondents.

Table 2 shows the results of a descriptive analysis of 62% of farmers assessing the attributes of innovation to adopting sex pheromone technology in the moderate category, with 37 farmers as respondents.

Table 3 shows the results of a descriptive analysis of 71.11% of farmers assessing external factors for adopting sex pheromone technology in the moderate category, with 42 farmers as respondents.

Table 4 shows the results of a descriptive analysis of 64.83% of farmers assessing the adoption of sex pheromone technology to be in the moderate category, with 39 farmers as respondents.

Table 1. Functional performance of farmer groups

No	Sub Variable	Percentage (%)		
		Low	Moderate	High
Before the Covid-19 pandemic				
1	Learning classes	0.00	80.00	20.00
2	Collaboration Platform	13.33	68.33	18.33
3	Production Units	0.00	60.00	40.00
During the Covid-19 pandemic				
1	Learning classes	0.00	80.00	20.00
2	Collaboration Platform	13.33	68.33	18.33
3	Production Units	0.00	58.33	41.67
	Average	4.44	69.17	26.39

Table 2. Diversity of innovation attributes

No	Sub Variable	Percentage (%)		
		Low	Moderate	High
Before the Covid-19 pandemic				
1	Relative advantage	8.33	48.33	43.33
2	Compatibility	0.00	75.00	25.00
3	Complexity	16.00	61.67	21.67
4	Triability	10.00	80.00	10.00
5	Observability	10.00	65.00	25,00
During the Covid-19 pandemic				
1	Relative advantage	8.33	48.33	44.00
2	Compatibility	0.00	75.00	25.00
3	Complexity	16.67	61.67	21.00
4	Triability	1.67	50.00	48.33
5	Observability	16.67	60.00	23.33
	Average	9.00	62.00	29.00

Table 3. Performance of external factors

No	Sub Variable	Percentage (%)		
		Low	Moderate	High
Before the Covid-19 pandemic				
1	Extension activities	10.00	65.00	25.00
2	Resources	10.00	81.67	8.33
3	Infrastructure	6.67	65.00	28.33
During the Covid-19 pandemic				
1	Extension activities	11.67	68.33	20.00
2	Resources	10.00	81.67	8.33
3	Infrastructure	6.67	65.00	28.33
	Average	9.17	71.11	19.72

Table 4. Adoption performance

No	Sub Variable	Percentage (%)		
		Low	Moderate	High
Before the Covid-19 pandemic				
1	Knowledge	10.00	73.33	16.67
2	Persuasion	0.00	68.33	31.67
3	Decision	5.00	68.33	26.67
4	Implementation	5.00	68.33	26.67
5	Confirmation	11.67	50.00	38.33
During the Covid-19 pandemic				
1	Knowledge	10.00	73.33	16.67
2	Persuasion	0.00	68.33	31.67
3	Decision	0.00	60.00	40.00
4	Implementation	5.00	68.33	26.67
5	Confirmation	11.67	50.00	38.33
	Average	5.83	64.83	29.34

3.2. Classic Assumption Test

Ghozali [13] mentions several conditions for carrying out a multiple linear regression test, including 1) Normality test, based on the analysis output results, the Asymp. Sig. (2-tailed) is 0.200> 0.05, and the data distribution follows the direction of the diagonal line. So, it can be concluded that the data distribution is normal, and the regression model is feasible because it fulfills the normality assumption. 2) Multicollinearity test, based on the analysis output results, all sub-variables have a tolerance value of >0.10 and a VIF value of <10. Thus, it can be concluded that there are no symptoms of multicollinearity between sub-variables in the regression model. 3) Heteroscedasticity test, based on the analysis output results, it can be seen that the plotting data is evenly spread above and below the 0 lines on the Y axis and the dots do not form a clear pattern. So it can be concluded that there is no symptom of heteroscedasticity in the research data. 4) Autocorrelation test, based on the results of the analysis there are no symptoms of autocorrelation because the Durbin Watson value (2.158) is between the dU value (1.600) and the 4-dU value (2.400).

4. Discussion

4.1. Multiple Linear Regression Test

A multiple linear regression analysis was performed after the data passed the classical assumption test. In the results of the regression analysis, the constant value is 0.595. It is positive, meaning that if the independent variable is zero, farmer adoption of sex pheromone technology will be worth 0.595. The coefficient of determination (R-square) value is 0.681, which means that the independent variable contributes 68.1% to the dependent variable.

Based on the results of the multiple linear regression analysis presented in Table 5 with a significant level of 1% and 5%, six indicators influence the adoption of sex pheromone technology, including learning class ($X_{1.1}$), production unit ($X_{1.3}$), compatibility ($X_{2..2}$), triability ($X_{2.4}$), observability ($X_{2.5}$), extension activities ($X_{3.1}$). Mean-while the other six indicators do not significantly influence Y because they have a significance value of >0.05. The COVID-19 pandemic as a dummy variable does not affect the adoption of sex pheromone technology because it has a significant value of 0.541>0.05 with 0.020 of an effect coefficient. Then the farmer adoption model equation in the application of sex pheromone technology is obtained as follows:

$$Y= 0.595 - 0.152X_{1.1} + 0.156X_{1.3} + 0.135X_{2.2} + 0.164X_{2.4} + 0.098X_{2.5} + 0.267X_{3.1}$$

Table 5. Multiple linear regression test results

Sub Variable	*Unstandardize Coefficient B*	T	Sig	Categories
R-square	0,681			
Constant	0,595	2,382	0,019	
Learning classes	**-0,152**	-3,824	**0,000**	**Significant**
Collaboration Platform	0,099	1,721	0,088	*Non-Significant*
Production Units	**0,156**	3,041	**0,003**	**Significant**
Relative advantage	0,025	0,334	0,739	*Non-Significant*
Compatibility	**0,135**	2,505	**0,014**	**Significant**
Complexity	-0,019	-0,208	0,836	*Non-Significant*
Triability	**0,164**	3,479	**0,001**	**Significant**
Observability	**0,098**	2,516	**0,013**	**Significant**
Extension activities	**0,267**	3,838	**0,000**	**Significant**
Resources	-0,019	-0,339	0,735	*Non-Significant*
Infrastructure	-0,056	-1,057	0,293	*Non-Significant*
Pandemi COVID-19	0,020	0,614	0,541	*Non-Significant*

4.2. Factors Influencing the Adoption of Sex Pheromones

The functional performance of farmer groups as learning classes significantly affects adoption of sex pheromone technology because it has a significant value of 0.000 <0.01. This result is inversely proportional to research by [14] which states that learning classes have no real influence on Y. The coefficient value of learning classes is -0.152 and is negative, meaning that the more learning activities are carried out, the lower the farmer's adoption of sex pheromone technology. Thus, it can be interpreted that if the unit of production ($X_{1.3}$), compatibility ($X_{2.2}$), triability ($X_{2.4}$), observability ($X_{2.5}$), and extension activities ($X_{3.1}$) are equal to zero (0), each increase in one-unit learning class ($X_{1.1}$) will increase the adoption of sex pheromone technology by -0.152. This result is because the material or information provided to farmers is often not following the conditions and needs of farmers which causes farmers to be reluctant to adopt an innovation. In line with the statement of [15] that learning classes in the low category tend to indicate that members of farmer groups still do not interpret farmer groups as learning classes, so the purpose of forming groups to improve group abilities has not gone as expected. The production unit has a significance value of 0.003 <0.05, which means that the production unit indicator has a significant influence on adoption.

Based on the results of the regression analysis, the unit of production indicator has a coefficient value of 0.156 with a positive direction, meaning when learning class ($X_{1.1}$), compatibility ($X_{2.2}$), triability ($X_{2.4}$), observability ($X_{2.5}$), and extension activities ($X_{3.1}$) are equal to zero (0), every one-unit increase in production unit ($X_{1.3}$) will increase the adoption of sex pheromone technology by 0.156. Stimulants that can be given to strengthen the function of farmer groups as production units are provided by making farmers aware of the existence of farmer groups which are business entities that can be developed to achieve economies of scale, both in terms of quantity, quality, and continuity [15].

Compatibility has a significance value of 0.014, which means that the compatibility indicator has a significant influence on Y. Based on the regression analysis results, the compatibility indicator has a coefficient value of 0.135 <0.05 in a positive direction, meaning that if the learning class ($X_{1.1}$), production units ($X_{1.3}$), triability ($X_{2.4}$), observability ($X_{2.5}$), and extension activities ($X_{3.1}$) are equal to zero (0), each one-unit increase in compatibility ($X_{2.2}$) will increase the adoption of sex pheromone technology by 0.135.

The results of the descriptive analysis show that compatibility is in the moderate category, which means that the sex pheromone technology is quite suitable. Based on interview results, some farmers do not want to apply sex pheromone technology because farmers are used to using chemical pesticides to control onion caterpillar pests which they feel are faster and more effective. When viewed from the economic conditions, the sex pheromone is quite expensive. It is rarely found at the nearest agricultural kiosk, so it is one of the factors causing farmers to be reluctant to adopt sex pheromone technology. This result is in line with Wasilah *et al.* [16] that compatibility shows the adoption of innovation by respondent farmers including doubtful criteria because the innovation is not in accordance with the farmers' habits.

Triability has a significant value of 0.001 <0.01, meaning that the triability indicator significantly influences Y. Based on the regression analysis results, the triability indicator has a coefficient value of 0.164 in a positive direction. This result means that if the learning class ($X_{1.1}$), production units ($X_{1.3}$), compatibility ($X_{2.2}$), observability ($X_{2.5}$), and extension activities ($X_{3.1}$) are equal to zero (0), each increase in one-unit triability ($X_{2.4}$) will increase the adoption of sex pheromone technology by 0.164. The results of the descriptive analysis show that the triability is in the moderate category, which means that the sex pheromone technology can be tested first on a small land area.

Based on interviews with respondent farmers, sex pheromone technology is unsuitable for large land because it will cost a lot. In line with Wasilah *et al.* [16] that triability shows the adoption of innovation by respondent farmers is in a bad category, because these innovations are not suitable for testing on large and sustainable lands because they require high production costs.

Observability has a significance value of 0.013 <0.05, meaning that the observability indicator has an actual or significant influence on Y. Based on the regression analysis results, the observability indicator has a coefficient value of 0.098 in a positive direction. This result means that if the learning class ($X_{1.1}$), production units ($X_{1.3}$), compatibility ($X_{2.2}$), triability ($X_{2.4}$), and extension activities ($X_{3.1}$) are equal to zero (0), each one-unit increase in observability ($X_{2.5}$) will increase the adoption of sex pheromone technology by 0.098. These results are inversely proportional to Effendy's research [17], which states that observability has no significant effect on farmer adoption rates.

The results of the descriptive analysis show that observability is in the moderate category, which means that sex pheromone technology can be observed and communicated so that farmers can first see and feel the benefits of the technology. In this way, innovation can prove its effectiveness so that respondents can judge whether sex pheromones follow what they need and whether sex pheromones are effective in overcoming onion caterpillar pest attacks.

Based on observations on pilot plots, sex pheromone technology gave good results in controlling onion caterpillar pests and was proven to reduce the use of chemical pesticides by 60 percent. This statement is in line with [14], who stated that applying sex pheromone technological innovations to shallot cultivation can reduce the use of insecticides.

Extension activities have a significance value of 0.000 <0.01, which means that indicators of extension activities have a significant effect on Y. Based on the regression analysis results, the compatibility indicator has a coefficient value of 0.267 in a positive direction, that if the learning class ($X_{1.1}$), production units ($X_{1.3}$), compatibility ($X_{2.2}$), triability ($X_{2.4}$), and observability ($X_{2.5}$) are equal to zero (0), each increase of one-unit extension activities ($X_{3.1}$) will increase the adoption of sex pheromone technology by 0.267. This result aligns with [10], which states that extension activities exist.

The results of the descriptive analysis show that extension activities are in the moderate category, which means that extension activities have quite an effect on adoption of sex pheromone technology. Pujiharti and Ernawati [18] state that the higher the frequency of extension and technology discussion by extension workers to farmer groups, the faster the technology distribution.

The COVID-19 pandemic as a dummy variable has a significance value of 0.541> 0.05, which means it has no significant effect on farmer adoption rates. The regression coefficient value of the COVID-19 pandemic is 0.020. It is positive, meaning that the COVID-19 pandemic can impact farmer adoption of the application of sex pheromone technology, even though the increase is very low, assuming that other variables have constant or fixed values. These results are aligned with Pratama's research [19], which states that the COVID-19 pandemic has not affected the empowerment of farmers. The COVID-19 pandemic has caused changes in social conditions in society, one of which is social restrictions. However, this condition did not affect farmers' adoption of sex pheromone technology because it was suspected that did not significantly impact on agricultural activities in Tarogong Kaler District.

4.3. Adoption Increasing Strategy

The strategy for increasing the adoption of sex pheromones is a formulation from the results of multiple linear regression analysis and descriptive analysis so that it can be formulated as shown in Figure 2.

Adoption of sex pheromones in general is in the moderate category (64.83%) which is influenced by extension activities (0.267), triability (0.164), the unit of production (0.156), compatibility (0.135), and learning class (-0.152). The formulation of the priority scale in extension activities refers to the coefficient value of each indicator on the results of the regression analysis, which is supported by the results of the descriptive study. The strategy to increase adoption is carried out by maximizing the factors that influence the adoption of sex pheromone technology, one of which is through extension activities. In this case, the selected material is related to sex pheromone technology, group administration, information sources, and presentation of the results of pilot plots using a combination of several extension methods such as lectures, discussions, method demonstrations, and demonstrations of results that are strengthened using media in the form of leaflets, power points, tools, and use of trap materials, as well as the pilot plot results.

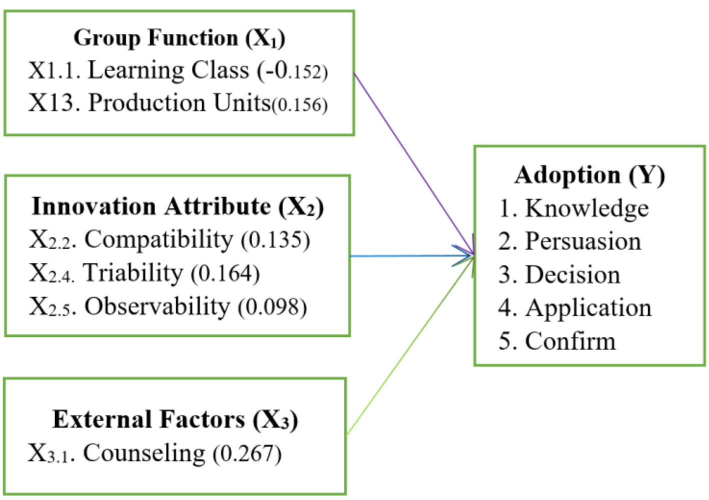

Figure 2. Extension strategy model

5. Conclusions

1. Most respondent farmers (64.83%) agree that the adoption, especially regarding knowledge, persuasion, decision-making, application, and efforts to confirm sex pheromone technology, aligns with expectations. Most respondent farmers (69.17%) agree that the function of farmer groups, especially class studies and production units, determines the adoption of sex pheromones' effect on applying sex pheromone technology. Most respondent farmers (62%) agree that the attributes of innovation, particularly triability, compatibility, and observability, determine sex pheromone adoption. Agricultural extension activities are considered to play a significant role in the adoption of sex pheromones by the majority of respondent farmers (71.11%).
2. The factors that influence the adoption of sex pheromones are agricultural extension activities ($p<0.01$), then the function of farmer groups as a learning class ($p<0.01$), and a production unit ($p<0.05$). In contrast, the innovation attributes that influence the adoption of sex pheromones are: characteristics of suitability that can be tried and observed.
3. The strategy for increasing the adoption of sex pheromones is carried out by optimizing agricultural extension to farmer groups with consideration of the material according to the needs of farmers, it can be tried on a small scale, and the results can be observed.

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