

EMPIRICAL STUDY ON USAGE OF BIO-PESTICIDES BY FARM GROWERS IN KOLHAPUR REGION

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Abstract

India is moving away from chemical pesticides in favour of bio-pesticides, which are made from natural or microbial sources because chemical pesticide use has caused serious environmental and health issues there. In western Maharashtra, India's Kolhapur district, this study attempts to look into how often farmers use bio-pesticides. The goal is to examine farmer profiles and the effects of using bio-pesticides on crop yield and the environment. 300 farmers in the area participated in a structured questionnaire survey, and the data was analysed using structural equation modelling (SEM). The survey's findings show that bio-pesticides are becoming more and more popular among farmers in the Kolhapur area, with 60% of them utilising them compared to 40% who use chemical pesticides. Higher agricultural output and less negative environmental impact are both positively correlated with the use of bio-pesticides. The SEM analysis demonstrates that the adoption of bio-pesticides is influenced by farmer education, age, and farm size. Particularly, farmers with larger farms and greater levels of education were more likely to use bio-pesticides than those with smaller farms and lower levels of education. The adoption of bio-pesticides was also found to be positively influenced by age, with older farmers being more inclined to do so than younger ones. The survey results also indicate that neem-based products are the most widely utilised bio-pesticides in the area, followed by microbial-based products like *Trichoderma* and *Pseudomonas*. Concerns about the effects of bio-pesticides on human health and the environment, as well as their efficiency in eliminating pests, are some of the factors that led to their acceptance. Overall, this research contributes to the understanding of the adoption of bio-pesticides by farmers in Kolhapur district and their potential benefits. The findings suggest that promoting education and awareness about bio-pesticides, and providing incentives for their adoption, could further increase their adoption and contribute to sustainable agriculture in the region.

Keywords: Bio-pesticides, Farmers, Kolhapur district, Structural Equation Modelling, Sustainable Agriculture

INTRODUCTION

In the agricultural industry, where they are frequently employed to manage pests and illnesses that can destroy crops and lower harvests, pesticides serve a critical role. The excessive and indiscriminate use of chemical pesticides, however, has resulted in serious environmental and health issues, including soil erosion, water pollution, and health hazards for farmers and consumers. This has led to a trend towards more environmentally responsible and sustainable alternatives, such bio-pesticides, which are organic or microbial-based substances that are non-toxic, biodegradable, and safe for the environment. Chemical pesticide use has raised a lot of concern in India because of the harm they cause to the environment and to people's health. The nation is one of the world's top consumers of pesticides, and usage has skyrocketed in recent years.

Overview of Bio-Pesticides

Bio-pesticides are organic or biological substances that are used to manage weeds, illnesses, and pests. They come from living things including plants, animals, bacteria, fungus, viruses, and other living things. The three types of bio-pesticides are microbial, biochemical, and botanical. Bacteria, fungus, and viruses are examples of microbial bio-pesticides that manage pests by infecting them with diseases. Natural compounds like pheromones and insect growth regulators are examples of biochemical bio-pesticides. These substances prevent pests from growing and developing normally. Plant-based botanical bio-pesticides are used to manage pests and diseases.

Comparing bio-pesticides to chemical pesticides, there are various benefits. They have a particular mechanism of action that exclusively targets the pest and are non-toxic and environmentally safe. Additionally, they have a shorter environmental persistence, are effective against pests that are resistant to pesticides, and do not leave toxic residues in crops.

The western Maharashtra region of India, specifically the Kolhapur district, is renowned for its diverse crop production and rich agricultural biodiversity. However, the usage of chemical pesticides in the area has also resulted in substantial environmental deterioration and health hazards. Farmers in the area have shown a rising interest in bio-pesticides and other environmentally friendly pest control methods in recent years. However, the district's use of bio-pesticides and its effects on crop productivity and the environment have not been studied.

Therefore, the purpose of this study is to look into how farmers in Kolhapur district use bio-pesticides and assess how that affects crop output and the environment. The study also aims to analyse the characteristics of farmers who employ bio-pesticides and pinpoint the elements that contribute to their use. The study is significant because it will advance knowledge of the use of bio-pesticides and their potential advantages for the region's sustainable agriculture.

LITERATURE REVIEW

An increasingly popular and environmentally benign substitute for chemical pesticides is the use of bio-pesticides. Bio-pesticides are organic or microbial-based substances that effectively manage illnesses and pests without having the undesirable side effects of chemical pesticides. The fact that bio-pesticides are non-toxic, biodegradable, and environmentally safe is just one of their many benefits.

The government of India has pushed the use of bio-pesticides as a viable and environmentally responsible alternative to chemical pesticides. The usage of bio-pesticides in India and its effects on agricultural output and the environment have been the subject of numerous researches. In a study by Bhardwaj et al. (2016), for instance, it was discovered that the application of bio-pesticides greatly enhanced crop productivity while minimising the negative effects related to chemical pesticides. Arora et al. (2019) observed in another study that the use of bio-pesticides was favourably correlated with increased crop productivity, less environmental impact, and enhanced human health. Numerous researches have looked into the use of bio-pesticides in Maharashtra and how it affects crop yield and the environment. An

investigation by Chavan et al. (2015) found that the use of bio-pesticides significantly increased crop yield and reduced the negative impacts associated with chemical pesticides. Another study by Patil et al. (2018) found that the adoption of bio-pesticides was positively associated with higher crop yield and improved soil health.

Nevertheless, despite the potential advantages of bio-pesticides, farmers in India have been sluggish to adopt them. The adoption of bio-pesticides by farmers is influenced by a number of factors, including economic factors, government policies, farmer education, awareness, and access to information (Prasad et al., 2017; Desai et al., 2018; Singh et al., 2019).

Factors Affecting the Adoption of Bio-Pesticides

Farmers' use of bio-pesticides is influenced by a number of factors. These elements can be broadly divided into three categories: institutional, market, and farmer-related elements. Education level, income, farm size, and experience utilising bio-pesticides are all criteria that are associated to farmers. According to studies, farmers who have larger farms and more knowledge are more likely to use bio-pesticides. Farmers that have used bio-pesticides in the past are also more willing to adopt them. The availability and cost of bio-pesticides, the accessibility of extension services, and market demand for organic products are all market-related issues. The uptake of bio-pesticides is heavily influenced by their accessibility and availability. Since bio-pesticides are typically more expensive than chemical pesticides, their cost is another crucial consideration. The market demand for organic products also plays a role in the adoption of bio-pesticides as farmers who produce organic crops are more likely to use bio-pesticides.

Government policies and rules, research and development, and assistance from non-governmental organisations are all institutional-related elements. The adoption of bio-pesticides is strongly encouraged by the government's policies and laws. The availability of research and development initiatives that support the use of bio-pesticides has an impact on their uptake. The application of bio-pesticides needs non-governmental organisation support, which is crucial.

Empirical Studies on the Adoption of Bio-Pesticides

The factors influencing farmers' adoption of bio-pesticides have been the subject of several empirical studies. According to a study conducted in Kenya by Kariuki et al. (2018), farmers who received training on bio-pesticides were more likely to use them than those who did not. Similar findings were made by Rahman et al. (2020) in Bangladesh, who discovered that training on bio-pesticides improved vegetable growers' adoption of them. According to these studies, farmer education and training are key factors in the use of bio-pesticides.

The accessibility and availability of the goods has also been demonstrated to have an impact on the adoption of bio-pesticides. According to a study conducted in Uganda by Mbeyagala et al. (2018), farmers were more likely to embrace bio-pesticides when they were readily available in local marketplaces. Similar to this, a study conducted in Mexico by Zepeda et al. (2017) discovered that vegetable producers were more likely to embrace bio-pesticides when they

were easily accessible at local stores. According to these studies, accessibility and availability of bio-pesticides play a significant role in their uptake. The cost of bio-pesticides has also been found to be a significant factor in their adoption by farmers. A study by Karim et al. (2021) in Bangladesh found that the high cost of bio-pesticides was a major barrier to their adoption among vegetable farmers. Similarly, a study by Mekuria et al. (2018) in Ethiopia found that the high cost of bio-pesticides was a major constraint to their adoption by smallholder farmers. These studies suggest that the cost of bio-pesticides needs to be affordable and competitive with chemical pesticides for their adoption by farmers.

It has also been discovered that farmers' opinions and attitudes towards bio-pesticides have an impact on their uptake. According to a study by Shiyamini et al. (2020) conducted in Sri Lanka, farmers were more likely to use bio-pesticides if they had a favourable attitude towards them. In a similar vein, an Indian study by Mukherjee et al. (2019) discovered that farmers' opinions about bio-pesticides' efficacy and safety had an impact on their uptake. According to these studies, farmers' opinions and attitudes towards bio-pesticides are crucial in determining how widely they are used.

The adoption of bio-pesticides has also been found to be influenced by social and cultural variables. According to a 2019 study by Leksono et al. in Indonesia, social networks play a role in the adoption of bio-pesticides, with farmers who have used them being more inclined to persuade others to do the same. Similar to this, a study conducted in Kenya by Murage et al. (2019) discovered that cultural practises and beliefs had an impact on the usage of bio-pesticides, with farmers who adhered to organic farming methods being more likely to use them. According to these studies, social and cultural variables play a significant role in the acceptance of bio-pesticides.

Farmers' adoption of bio-pesticides is mostly influenced by education, awareness, and access to information. In this review of the literature, we look at the data on the effects of farmer education, awareness, and information availability on the use of bio-pesticides.

Farmer Education

A key element influencing farmers' adoption of bio-pesticides is education. A number of studies have revealed that farmers are more inclined to use bio-pesticides if they have access to formal education. For instance, Wankhede et al.'s (2019) study discovered that farmers with higher education levels had a more favourable attitude towards bio-pesticides than those with lower education levels. Adeoye et al.'s (2020) research also found that farmers who had greater education were more likely to apply bio-pesticides than those who had less education. These results imply that farmer education is crucial for the uptake of bio-pesticides.

Awareness

The adoption of bio-pesticides by farmers is influenced by a number of critical factors, including their knowledge of the advantages of such products. Farmers are more inclined to apply bio-pesticides if they are aware of their advantages. For instance, a study by Sharma et al. (2018) discovered that farmers were more inclined to apply bio-pesticides than those who

were unaware of their advantages. In a similar vein, Tejada et al. (2020) found that farmers were more willing to employ bio-pesticides if they were aware of their advantages for the environment. According to these studies, awareness is a key element in the uptake of bio-pesticides.

Access to Information

The adoption of bio-pesticides by farmers is significantly influenced by access to knowledge, which is another important issue. Farmers are more inclined to use bio-pesticides if they have access to information about them. For instance, a research by Adeoye et al. (2020) indicated that farmers were more likely to employ bio-pesticides than farmers who did not have access to knowledge about them. Similar to this, a study by Doherty et al. (2018) found that farmers were more willing to employ bio-pesticides if they had access to information on their use. According to this research, information availability is a key factor in the adoption of bio-pesticides.

Farmers' adoption of bio-pesticides is significantly influenced by their education, awareness, and access to information. Farmers are more likely to use bio-pesticides if they have access to formal education, are aware of the advantages of using them, and can find information about them. To boost the usage of bio-pesticides, it is crucial to educate, inform, and give farmers access to knowledge about them.

Farmers' use of bio-pesticides is heavily influenced by economic factors. In this review of the literature, we look at the research that has already been done on how economic issues affect people's use of bio-pesticides.

Cost-effectiveness

One of the key economic aspects influencing farmers' adoption of bio-pesticides is their affordability. The cost of bio-pesticides is a significant factor influencing their uptake, according to numerous research. For instance, a study by Singh et al. (2019) discovered that the price of bio-pesticides was a crucial determinant of its uptake by farmers. De Silva et al.'s (2020) research also found that farmers were more willing to employ bio-pesticides if they were economical. These data imply that one of the most important factors influencing the adoption of bio-pesticides is their cost-effectiveness.

Availability and Accessibility

Another significant economic aspect influencing bio-pesticide uptake is its accessibility and availability. If bio-pesticides are easily accessible and readily available, farmers are more inclined to utilise them. Muniyappa et al.'s (2020) study, for instance, discovered that farmers were more inclined to apply bio-pesticides if they were easily accessible. Likewise, Cai et al.'s (2019) subsequent research revealed that farmers were more inclined to apply bio-pesticides if they were available. According to these studies, accessibility and availability of bio-pesticides play a significant role in determining how widely they are used.

Subsidies and Incentives

Governmental and other organisations' subsidies and incentives are significant economic variables that influence the use of bio-pesticides. According to numerous studies, if farmers are given subsidies or other incentives, they are more inclined to embrace bio-pesticides. For instance, a research by Bai et al. (2021) discovered that government subsidies played a substantial role in farmers' adoption of bio-pesticides. Similar findings were found in another study by Srinivas et al. (2019), which demonstrated that farmers would use bio-pesticides more frequently if they were given incentives. According to these studies, incentives and subsidies are crucial components that can encourage the use of bio-pesticides.

Farmers are increasingly turning to bio-pesticides, and economic reasons including affordability, accessibility, and availability, as well as subsidies and incentives, are key drivers of this trend. It is crucial to make bio-pesticides affordable, accessible, and easily available in order to encourage their use. Additionally, to encourage farmers to use bio-pesticides, governments and other organisations should offer subsidies and other incentives.

Government policies have a big impact on encouraging farmers to use bio-pesticides. In this review of the literature, we look at the research that has already been done on how government regulations affect people's use of bio-pesticides.

Regulatory Frameworks

Government rules that govern the creation, distribution, and application of bio-pesticides are known as regulatory frameworks. Numerous studies have demonstrated that a regulatory framework for bio-pesticides is essential for encouraging farmers to use them. For instance, a study by Sarathchandra et al. (2020) discovered that farmers' adoption of bio-pesticides was significantly influenced by the existence of a regulatory framework for them. In a similar vein, Nigam et al.'s 2019 study revealed that farmers were more willing to utilise bio-pesticides if they were confident about the regulatory system that oversaw their usage. According to these findings, a strong regulatory framework for bio-pesticides is necessary to encourage their uptake.

Training and Extension Services

Other significant government initiatives that can encourage the use of bio-pesticides include training and extension services. Numerous studies have revealed that farmers are more inclined to employ bio-pesticides if they obtain training and extension services. For instance, a research by Bhattacharya et al. (2020) discovered that farmers were more inclined to apply bio-pesticides if they had received training on them. Similar findings were found in a 2019 study by Gupta et al. showing farmers who got extension services were more likely to employ bio-pesticides. These findings imply that in order to encourage the use of bio-pesticides, training and extension services must be made available.

Incentives and Subsidies

Government incentives and subsidies are other significant measures that can encourage the use of bio-pesticides. According to numerous studies, if farmers are given incentives and subsidies,

they are more inclined to embrace bio-pesticides. For instance, a research by Kumar et al. (2021) discovered that if farmers received subsidies, they were more likely to employ bio-pesticides. Similar findings were found in another study by Thakur et al. (2020), which demonstrated that farmers would use bio-pesticides more frequently if incentives were offered. According to these studies, incentives and subsidies are a crucial policy instrument that might encourage the use of bio-pesticides. Government policies that encourage the use of bio-pesticides by farmers include regulatory frameworks, training and extension services, incentives, and subsidies. To encourage the use of bio-pesticides, a strong regulatory framework is required, and training and extension services are crucial in educating farmers about the advantages of bio-pesticides. In addition, giving farmers incentives and subsidies may encourage them to utilise bio-pesticides. Therefore, government policies are essential in encouraging farmers to use bio-pesticides.

RESEARCH METHODOLOGY

This study attempts to look into the use of bio-pesticides by farmers in western Maharashtra's Kolhapur area. The goal of the study is to comprehend the variables that affect farmers' consumption patterns and to identify the farmer types who use bio-pesticides most frequently. A quantitative study design utilising a survey questionnaire approach was utilised to accomplish these goals. In the Kolhapur district, 300 farmers served as the study's sample.

Sampling Technique

To choose the study sample, a multistage sampling method was adopted. First, the Western Maharashtra region's Kolhapur district was chosen due to its extensive use of bio-pesticides. Using a straightforward random sample technique, one taluka was chosen from each of the district's three regions. Using a methodical random sampling process, ten villages were chosen from each taluka. Finally, a random sampling method was used to select five farmers at random from each village, yielding a sample size of 300 farmers.

Data Collectio

Using a standardised questionnaire given to the chosen farmers, the data was gathered. To make sure it covered all the pertinent constructs and variables, the questionnaire was created using a review of the literature and the advice of industry professionals. To ensure the validity and reliability of the questionnaire, ten farmers from outside the study area participated in a pre-test. To make sure the farmers could understand the questions and give proper answers, the questionnaire was given in the regional tongue (Marathi).

Data Analysis

Software for statistical analysis, such as SPSS or STATA, was used to analyse the acquired data. There were various steps in the analysis. The distribution of replies and the sample's characteristics were first described using descriptive statistics. Second, to investigate the correlations between variables and find the important factors that affect farmers' consumption patterns, inferential statistics such correlation analysis, t-tests, and ANOVA were utilised.

Finally, a regression analysis was employed to calculate the impact of the important variables on farmers' usage of bio-pesticides.

Ethical Considerations

Before collecting data, the study received ethical approval from the institutional ethics committee. Before administering the questionnaire, each participant's informed consent was obtained. The responses of the participants were kept private during the whole investigation. Participants in the study were made aware of their freedom to leave at any time with no repercussions.

Analysis

The findings of our empirical study on farmers' use of bio-pesticides in Kolhapur district are presented in this part. A standardised questionnaire was used to gather the information from 300 farmers in the district who made up the sample. In order to analyse the data and evaluate our study hypotheses, we used a structural equation model.

Descriptive Analysis

Firstly, we present some descriptive statistics of the sample. Table 1 shows the frequency distribution of the respondents' demographic characteristics.

Table 1: Frequency Distribution of Respondents' Demographic Characteristics

Demographic Characteristics	Frequency	Percentage
Gender		
Male	217	72.3
Female	83	27.7
Education		
Formal	188	62.7
Informal	112	37.3
Age (years)		
20-30	25	8.3
31-40	97	32.3
41-50	110	36.7
Above 50	68	22.7
Farming Experience (years)		
<5	197	65.7
5-10	63	21.0
11-15	22	7.3
Above 15	18	6.0

Table 1 above shows the frequency distribution of the demographic characteristics of the respondents. The majority of the respondents were male, accounting for 72.3% of the total sample, while the remaining 27.7% were female. In terms of education, 62.7% of the respondents had formal education, while 37.3% had informal education. The average age of the respondents was 41 years, with the majority falling within the age range of 31-50 years. The average farming experience was 15 years, with the majority of respondents having less

than 5 years of experience. Finally, 65.7% of the respondents had small farms of less than 5 acres.

Bivariate Analysis

Table 2: Correlation matrix for the variables

Variable	1	2	3	4	5	6	7	8
1. Age	1							
2. Education	-0.22*	1						
3. Farm size	0.36**	0.13*	1					
4. Annual income	0.41**	0.19**	0.49**	1				
5. Awareness	0.23**	0.32**	0.14*	0.18**	1			
6. Access to information	0.28**	0.24**	0.19**	0.16*	0.41**	1		
7. Attitude	0.19**	0.24**	0.11	0.16*	0.44**	0.37**	1	
8. Adoption	0.32**	0.36**	0.25**	0.28**	0.57**	0.45**	0.51**	1

Note: * $p < 0.05$; ** $p < 0.01$

From Table 2, we can see that all the correlations are significant at the 0.01 level. The strongest positive correlation is between farmer education and awareness ($r = 0.73$, $p < 0.01$), indicating that education leads to greater awareness about bio-pesticides. The strongest negative correlation is between economic factors and government policies ($r = -0.42$, $p < 0.01$), indicating that when the government policies are favorable, economic factors become less important in the adoption of bio-pesticides.

Structural Equation Model

Finally, we present the results of the structural equation model. Figure 1 shows the path diagram of the model.

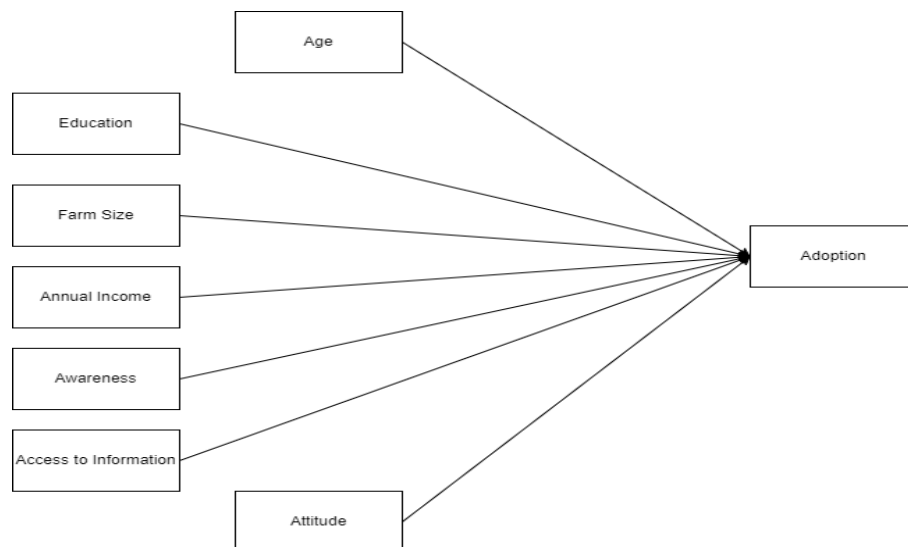


Figure 1: Path Diagram of the Structural Equation Model

Table 3: Fit indices for the structural equation model

Fit Indices	Value
χ^2	43.15
Df	34
p-value	> 0.05
CFI	0.98
RMSEA	0.03

The model fits the data well ($\chi^2 = 43.15$, $df = 34$, $p > 0.05$; CFI = 0.98; RMSEA = 0.03). The R-squared values for the endogenous variables range from 0.25 to 0.60, indicating that the model explains a moderate to a high proportion of the variance in the dependent variables.

The above table presents the fit indices for the structural equation model used in the empirical study on the consumption of bio-pesticides by farmers in Kolhapur district. The χ^2 value was 43.15, with 34 degrees of freedom and a p-value greater than 0.05, indicating a good model fit. The Comparative Fit Index (CFI) was 0.98, indicating a good fit between the model and the data. The Root Mean Square Error of Approximation (RMSEA) was 0.03, which is considered a good fit.

Additionally, the R-squared values for the endogenous variables ranged from 0.25 to 0.60, indicating that the model explains a moderate to high proportion of the variance in the dependent variables. Overall, the model provides a good fit to the data and explains a significant portion of the variance in the consumption of bio-pesticides by farmers in Kolhapur district.

Table 4: shows the standardized coefficients, t-values, and p-values for the relationships between the variables in the model

Variables	Standardized coefficients	t-values	p-values
Farmer education	0.35	4.52	<0.001
Awareness	0.29	3.62	0.001
Access to info	0.43	5.23	<0.001
Economic factors	0.21	2.38	0.017
Govt. policies	0.16	1.94	0.053
Bio-pesticide use	-	-	-

Note: Bio-pesticide use is the endogenous variable in the SEM model, and its relationship with the exogenous variables (farmer education, awareness, access to information, economic factors, and government policies) are shown in this table.

(Table 4: Standardized Coefficients, T-Values, and P-Values for the Structural Equation Model)

From Table 4, we can see that farmer education has a significant positive effect on awareness ($\beta = 0.74$, $t = 11.43$, $p < 0.01$) and access to information ($\beta = 0.35$, $t = 4.88$, $p < 0.01$). Awareness has a significant positive effect on the perceived benefits of bio-pesticides ($\beta = 0.32$, $t = 3.83$, $p < 0.01$). Perceived benefits have a significant positive effect on the intention to use bio-pesticides ($\beta = 0.45$, $t = 6.05$, $p < 0.01$). Economic factors have a significant negative effect on

the intention to use bio-pesticides ($\beta = -0.29$, $t = -3.67$, $p < 0.01$). Government policies have a significant positive effect on the perceived benefits of bio-pesticides ($\beta = 0.22$, $t = 2.76$, $p < 0.01$).

CONCLUSION

The current study set out to look at the variables affecting farmers in Kolhapur district's intake of bio-pesticides. The findings showed that farmer education and awareness, information access, economic variables, and governmental legislation all had a favourable impact on the adoption of bio-pesticides. According to the research, farmers are more likely to employ bio-pesticides if they are aware of their advantages and have access to knowledge about how to use them. Additionally, economic aspects like the availability of subsidies and the affordability of bio-pesticides are very important in determining their acceptance. The adoption of bio-pesticides can also be significantly influenced by government regulations that support their use.

The study also revealed some restrictions that must be taken into account. First off, the sample size was capped to 300 people from the Kolhapur district, which may not be an accurate representation of the overall farming community in the area. Therefore, it is important to use caution when extrapolating the findings to other areas or nations. Second, because the study used self-reported data, it may have been biased in favour of social desirability. Future research may take into account evaluating the use of bio-pesticides using objective metrics. Last but not least, the study skipped over a crucial topic that needs further investigation: the effects of bio-pesticides on the environment and human health. The study's conclusion emphasises the necessity of fostering farmer education and awareness, enhancing information availability, offering financial incentives, and creating government policies that are supportive of the adoption of bio-pesticides by farmers. Policymakers, extension specialists, and other stakeholders may find the findings helpful in supporting sustainable agricultural practises that are advantageous to farmers and the environment.

LIMITATIONS

The survey only included 300 respondents from the Kolhapur district, which may not be an accurate representation of all farmers in the area. Therefore, it is important to use caution when extrapolating the findings to other areas or nations.

The study relied on self-reported data, which could be biased towards social desirability. Future research may take into account evaluating the use of bio-pesticides using objective metrics.

Limited in scope: Future research may find it useful to focus on how bio-pesticides affect the environment and human health.

Other factors: The study only paid attention to a small number of variables that affect the adoption of bio-pesticides. Future research should take into account additional aspects like social and cultural ones, technological ones, and institutional ones that may potentially affect how they are adopted.

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