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Investigating the Effective Factors on Farmers' Participation in Using Biological Pest Control Methods in Torshiz Area

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ABSTRACT

Background: Knowing the factors affecting the acceptance and use of biological control technologies can help to find a solution to the problem of acceptance of farmers' participation. This study aimed to investigate factors influencing farmers' acceptance of biological pest control methods in the Torshiz area of Khorasan Razavi.

Methods: This study involved descriptive-analytical research using structural equation modeling. The statistical population included 100 farmers of the region, 95% of respondents were male and 5% were female, and the questionnaires were completed in person. The validity of the studied constructs was investigated using confirmatory factor analysis (CFA). Using the reliability of the questionnaire, the distribution of 30 questionnaires among the target population and their completion and collection was determined by calculating the Cronbach's alpha. Also, Friedman's rank test was used to assess the relative importance of items and prioritization of factors. The data analysis was conducted using SPSS software version 22 and the structural model was achieved in PLS Software version 3.

Results: The results indicated that the significance level of Friedman's test is less than 0.05, suggesting that the items did not have the same importance across all four factors. The results showed that the most effective factors contributing to the acceptance of biological pest control methods were in the attitudinal category, followed by economic and social factors. The study also ranked the influential components in four factors.

Conclusion: To enhance the acceptance of sustainable technologies for producing high-quality products in the Torshiz area, it is crucial to consider the costs of pesticides and learn from the positive experiences of other farmers who have adopted biological pest control methods.

1. Introduction

Currently, plant diseases and insect infestations are mainly controlled by excessive use of pesticides, and farmers rely on the appropriate selection of fertilizers and pesticides to improve crop yields and control pests. Unfortunately, the indiscriminate use of such agricultural chemicals can cause ecological and environmental problems as well as risks to human health (Sehrawat et al., 2022). For example, the indiscriminate use of chemical pesticides can cause pesticide residues to remain in crops and increase the resistance of pests to poisons due to their continuous use, pollution of soil, water, and air, and reduction of biodiversity due to loss of microflora and non-target animals (Geiger et al., 2010; Trevisan et al., 2024). The adverse effects of pesticides on ecosystems, microorganisms, animals, beneficial insects, plants, and human health and increasing pest resistance have increased efforts to find an alternative strategy that is cost-effective, low-risk, and target-specific. Biological control has been widely considered as one of the most

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important options for pest management, which reduces the use of chemicals and preserves human and environmental health (Daraban et al., 2023; Zhou et al., 2025). Acceptance of new technologies can provide opportunities for farmers to improve incomes, increase yields, the importance of sustainable agriculture, and food security. In the field of agriculture, it is very rare that farmers have the necessary ability and want to accept new technologies (Mariano et al., 2012). On the other hand, farmers can use nature-based methods (biological control) such as using animals, plants, bacteria, and minerals to improve crop performance and pest control (Harman et al., 2010; Nchu, 2024). Biological control is using living organisms to suppress the population density or the effect of a specific pest organism, which reduces its abundance or damage. It also provides a promising solution to achieve flexibility and sustainability in agricultural systems (Sentis et al., 2022). In fact, as a part of sustainable pest management, biological control is one of the most important ecosystem services that ensures the nutritional health of organisms, especially humans, and preserves the quality of the environment, and is also one of the requirements of sustainable agricultural development (Koranyi et al., 2022). Biopesticides and biofertilizers have great potential for use in organic and conventional agricultural practices as methods of biological pest control (Gardener & Fravel, 2002; Jaber & Enkerli, 2016; Rady et al., 2020; Ramakuwela et al., 2020). Therefore, in the field of factors affecting farmers' participation in the use of biological pest control methods, there are many factors. In this field, studies have been done by some researchers, and we will review some of them. Gajanana et al. (2006) examined the economic adoption of integrated pest control technology in a tomato and showed that the use of this biological control method can economically manage tomato pests and diseases. Hasanimoghaddam et al. (2012) analyzed the bottlenecks and challenges of the development of biological technology control in the management of the figurant against rice stem borer from an economic-social point of view. The most important factors in the acceptance of this technology were, in order, the risk aversion of rice farmers, the value of the product per hectare, the number of plots of land, the number of times Trichogramma bees were released, the use of this technology in adjacent fields, the area under cultivation, the experience of using the technology, age of the farmer and participation in promotional classes. Rodrigues et al. (2023) investigated the effects of using biological pest control on the technical efficiency of the Brazilian agricultural sector. The study also considered the impact of factors such as technical assistance, rural financing, and membership in cooperatives or class institutions on efficiency measures. The results showed that the strong adoption of biological control can increase the productive performance of the Brazilian agricultural sector. Omokaro (2024) investigated the perceptions and practices of farmers in Delta and Edo states in southern Nigeria regarding pest and disease control methods. A survey of 160 farmers, 80 from each state, was conducted to collect data on demographic characteristics, pest management strategies, and understanding of soil fertility loss due to artificial inputs. The findings highlight the need for increased education about sustainable agricultural practices and local research on the long-term effects of artificial inputs on soil health. In the field of biological pest control technologies, various factors come into play, some of which have been highlighted in previous research. Furthermore, to incentivize farmers to adopt biological control agents and biofertilizers while reducing the overreliance on pesticides and toxic chemical fertilizers, it is imperative to thoroughly investigate and pinpoint the factors that entice farmer involvement in these methods within each specific region. This study has been dedicated to identifying the factors that influence the adoption of biological pest control methods among farmers in the Torshiz area. By leveraging these insights, planners in the agricultural sector can significantly improve the performance of agricultural products and effectively advocate for the use of biological pest control methods.

2. Materials and Methods

2.1 Study area

This research was conducted in the Torshiz area which covers an area of 7206 km^2 and is located in Khorasan Razavi province of Iran. A major part of this area is the plain and the rest is the highlands. This basin is located in the geographical range of 57° 52′ 08″ to 58° 37′ 15″ east longitude and 34° 49′ 14″ to 35° 32′ 56″ north latitude. The most important residential area is Kashmar city, which is the center of Kashmar city in Khorasan Razavi province. The Torshiz area includes parts of Kashmar, Kuhsorkh, Khalil Abad, and Bardaskan cities, and cities such as Kashmar, Khalil Abad, Kander, and Bardaskan are located in this basin. The most important agricultural and horticultural products of this region are wheat, barley, alfalfa, grapes, almonds, and saffron (Esmaeili Jelodar & Heydari, 2020; Mohammadi & Hedayat Shishvan, 2022).

2.2 Research method

In terms of purpose, this research is applied and in terms of method, it is a type of structural equation modeling research, which is descriptive-analytical research along with fieldwork. In this regard, some researchers, including Viechtbauer (2015) have confirmed that a minimum sample size of 100 participants is necessary. Also, the PLS Software was used to make this model which needs minimal data Even just 30 questionnaires were enough to implement the model (Aibinu & Al-Lawati, 2010). To conduct this research, at the beginning, previous sources and research that were in line with the topic of this research were reviewed. The dependent variable of this research is the factors influencing the adoption of biological pest control methods, and the theoretical framework and independent variables of this research include economic, social, educational, and attitudinal factors of farmers. The structural equations model was used to identify the effective factors in the adoption of biological pest control methods. To do this, a questionnaire

was used to collect information to identify the influencing factors. The statistical population of the research was made up of the farmers of the Torshiz area of Khorasan Razavi (farmers of Kashmar, Khalil Abad, Bardaskan, and Rivash). The statistical sample of the area included 100 people who the farmers completed face-to-face using the questionnaire method (Adeli-Sardooei et al., 2015). To analyze the data, SPSS software version 22 was used. The questionnaire included general questions about the general characteristics of farmers (name, age, education, land address), type of land ownership, cultivation area, type of crop, and type of pest control method. In addition, questions related to educational factors (8 questions), economic factors (11 questions), social factors (13 questions), and attitudinal factors (12 questions) were designed. The answers to the general questions were descriptive and the answers to the questions related to the four factors under study were done using a Likert scale and by selecting the options very little (1), little (2), medium (3), much (4), and very much (5). To check the validity of the questionnaire, the opinions of experts in this field (university professors and relevant experts in agricultural engineering, biology, plant diseases, and the environment) were used. In this research, construct validity was used using confirmatory factor analysis (CFA). These factors are shown in Tables 1 and 2. Also, using the reliability of the questionnaire, the distribution of 30 questionnaires among the target population and their completion and collection was determined by calculating the Cronbach's alpha coefficient which the value was determined 0.94.

3. Results and Discussion

To achieve the goals of the research, the economic, social, educational, and attitudinal factors of farmers towards the acceptance of biological pest control methods in the Torshiz area of Khorasan Razavi province have been investigated. These factors were investigated by the questionnaire survey. The general results of completing the questionnaire showed that most of the respondents (95%) were men and 5% were women, the mean and standard deviation of the age of the studied sample were 44 and 12.46 years, the most educated people were Below high school diploma (15.2%), High school diploma (43%), Associate degree (2.5%), Bachelor (12.7%), and 97.5% of land ownership type is ownership and 2.5% is leased. The type of cultivation of most of the respondents (97.5%) was garden and 2.5% was arable. The products of most respondents include pistachios (87.3%), grapes (1.5%) and other products. Also, all the respondents used chemical poisons to figurate against pests. The result of this survey for Investigating the Effective Factors on Farmers' Participation in Using Biological Pest Control Methods in Torshiz Area has been presented in the following:

3.1 Prioritizing items in each factor

To prioritize the items associated with each of the educational, economic, attitudinal, and social factors according to their respective position on a 5-point Likert scale, Friedman's rank test was used to assess the relative importance of the items. This methodology was used in each factor, facilitating the prioritization of the factors (Mazhari et al., 2017). The results showed that the significant level of Friedman's test was less than 0.05 and the items do not have the same importance. The ranking of items based on the average ratings is shown in Tables 1 to 2. As can be seen in Table 1, within the educational factors, the role of technologies related to biological pest control emerged as the most effective component with an average rating of 3.44, while health management of manufactured products was the least effective component, with an average rating of 1.51. These findings suggest that, at the confidence level of 0.95, the components related to educational factors do not have the same ranks. Table 1 also shows the prioritization of economic factors. The results indicate that reducing pesticide costs was the most effective component, with an average rank of 4.44, whereas the ability to diverse cultivation practices received the lowest average rank of 3. Similar to the educational factors, it can be concluded that the components related to economic factors do not have the same ranks at the 0.95 confidence level.

Table 1. Prioritization of educational and economic factors

Factors	Prioritization	Mean	Standard deviation	Rank
Educational	Technologies related to biological pests' control	3.44	0.971	1
	The methods of biological pest control	3.14	1.152	2
	Expertise in utilizing biological methods for pest control	3.01	0.967	3
	Production of organic products	2.63	1.002	4
	Planning to grow crops with minimal use of chemical pesticides	2.08	1.083	5
	Biological Pest Control Calendar according to the method and the type of cultivation	1.73	0.858	6
	Appropriate timing for pest control	1.65	0.833	7
	Health management of manufactured products	1.51	0.904	8
	Friedman test statistic 288/2489	df = 7	*P-value* = 0.0001	
Economic	Reducing pesticide costs	4.44	0.764	1
	Increasing the amount of production per unit area	4.42	0.871	2
	Reduce labor costs	4.25	0.854	3
	Pest reduction	4.20	0.939	4
	Reduce weed and its control costs.	3.97	1.000	5
	Ensure timely provision of facilities and long-term repayment of loans.	3.91	1.351	6
	The low interest rate of bank facilities	3.72	1.368	7
	The advice of technical experts to use biological pest control methods	3.59	0.954	8
	The possibility of utilizing adequate banking facilities	3.48	1.385	9
	The farmer's investment capability	3.03	0.987	10
	Diverse cultivation capability	3.00	1.109	11
	Friedman test statistic 181/963	df = 10	*P-value* = 0.0001	

Table 2 presents the prioritization of social factors. The findings reveal that using positive experiences of others with biological pest control methods had the most significant impact, with an average rating of 4.33, while the introduction of biological methods in promotional publications was rated the least impactful, with an average rating of 2.19. Furthermore, these results indicate that the components related to social factors do not have the same ranks at the confidence level of 0.95. Table 2 shows the prioritization of the components of attitudinal factors. Based on this, the methods that increase the quality of manufactured products with an average rating of 4.75 have the most impact and the struggle with traditional thoughts in agriculture with an average rating of 3.67 has the least impact. At the confidence level of 0.95, it can be said that the components related to attitudinal factors do not have the same ranks. According to the ranking of the influential components in four educational, economic, social, and attitudinal factors, it can be concluded that to increase the quality of manufactured products to accept healthy technologies related to biological control in the Torshiz area, it is necessary to pay attention to the costs of pesticide and take advantage of other positive experiences of farmers in using biological methods of pest control. The results of this research are consistent with the study of Bailey et al. (2010) regarding the social and economic drivers shaping the future of biological control from the Canadian point of view. Their research identified key factors affecting the development and use of microbial biopesticides, highlighting how the actions of government, farmers, and industry can lead to changes in improving the quality of products and accepting biological pest control technologies.

Table 2. Prioritization of social and attitudinal factors

Factors	Prioritization	Mean	Standard deviation	Rank
Social	Using the positive experiences of others with biological pest control methods	4.33	0.873	1
	Protection of soil quality	4.04	0.940	2
	Ensuring the removal and control of pests using biological methods	3.92	1.118	3
	Convenient access to stores supplying biological research methods	3.76	0.909	4
	Providing training that explains biological methods	3.47	1.036	5
	Participation in training courses related to the use of biological methods	3.43	1.035	6
	Educational visits to areas with the implementation of biological methods	3.44	1.094	7
	Convenient access to services for biological pest control methods	3.35	1.075	8
	Introducing biological methods of pest control on radio and television	3.16	1.067	9
	Advertisements of sellers and suppliers of biological products and services	3.16	1.031	10
	The proper treatment of executives and individuals involved in biological processes	3.09	0.865	11
	The level of your risk-taking associated with using these methods	2.96	0.898	12
	Introducing the use of biological methods in promotional publications	2.19	1.039	13
	Friedman test statistic 230/97	df = 12	*P-value* = 0.0001	
Attitudinal	The methods increase the quality of manufactured products	4.75	0.588	1
	The methods increase the income and profit of the family.	4.66	0.638	2
	The methods increase the quantity (amount) of manufactured products.	4.56	0.549	3
	They are associated with economic benefits, particularly cost reduction.	4.46	0.765	4
	They preserve the health of the products.	4.42	0.841	5
	Causing greater success in farm management	4.33	0.780	6
	They are effective in protecting the environment.	4.27	0.943	7
	They prevent the waste of time and costs of agriculture.	4.25	0.776	8
	These methods are compatible with traditional approaches and local knowledge.	4.19	0.935	9
	They are technically feasible.	4.03	0.784	10
	Farmers have more access to facilities and credits.	3.96	0.884	11
	They cause struggle with traditional thoughts in agriculture.	3.67	0.858	12
	Friedman test statistic 181/963	df = 10	*P-value* = 0.0001	

3.2 Measurement and structural models

In the methodology of the structural equation model, it is first necessary to check the validity of the studied structures to determine that the indicators selected for measuring the desired structures have the necessary accuracy. For this purpose, confirmatory factor analysis (CFA) was used. In such a way that the factor load of each indicator with its structure must have a value of t higher than 1.96 (Ghasempour et al., 2022). In this case, this indicator has the necessary accuracy to measure the structure or attribute of the latent. If the indicators of the studied structures have a value of t less than 1.96, they do not have the necessary importance for measurement. Therefore, they should be excluded from the analysis process, which leads to the removal of some questions from the analysis. After that, the model was re-examined and the validity of the structure was done to check the accuracy and importance of the selected indicators for measuring the structures. The results showed that the items provided suitable factorial structures to measure the studied variables in the research model (Aazami & Hashemiamin, 2018). In structural equation modeling, in addition to construct validity, other criteria, including reliability and validity, should be evaluated to check the variables, which will be discussed further. To check the reliability, a composite reliability index was used, the results of which are shown in Table 3. Reliability means that there was the same understanding of the questions among the different respondents studied. In the methodology of the structural equation model, the composite reliability coefficient was also used, and values higher than 0.7 for each structure indicate its appropriate reliability. Also, the values of the average variance extracted (AVE) were higher than 0.5 in all cases, which indicates the appropriate reliability and validity of the investigated factors (Cheung et al., 2024).

Table 3. Examination of AVE values and reliability indices

Factors	Cronbach's Alpha	Rho-A	Composite Reliability	AVE
Adoption of biological pest control methods	0.885	0.906	0.901	0.581
Attitudinal	0.836	0.849	0.879	0.515
Economic	0.794	0.821	0.859	0.555
Educational	0.786	0.778	0.84	0.516
Social	0.859	0.874	0.892	0.514

For the structural model, at this stage, considering the completion of the variable refinement phase and ensuring the accuracy of the indicators in measuring related variables, the research hypotheses can be tested. Assumptions were examined in the form of structural equations model and the direction of the structural model was evaluated. Each path corresponds to one of the hypotheses of the model. Each hypothesis is tested by examining the sign, size, and statistical significance of the path coefficient (beta) between each latent variable and the dependent variable. This path coefficient is higher, the influence of the latent variable will be greater than the dependent variable. Considering the results of the study of the relationship between independent and dependent structures using the relevant coefficient, it is possible to examine the significance of the effects between the research structures. To investigate the significance of the path coefficient or beta, the significance of the T-value for each path coefficient should be considered. Therefore, the bootstrap method was used to measure the significance of this method. The results showed that all the investigated factors had an impact on the acceptance of biological pest control methods (T-statistics greater than 1.96 (for Attitudinal factors = 17.085, Economic factors = 9.925, Educational factors = 6.144, and Social factors = 25.636) and significant level less than 0.05 (*P-value* = 0.0001 for all factors)) and social factors and then attitude factors had the greatest impact. The research model is shown in Figure 1 (a and b) with t-statistics and path coefficients. The normality of the data was tested using kurtosis and skewness tests.

3.3 Examining the answers to research hypotheses

3.3.1 Hypothesis 1

Using the questionnaire, it is possible to identify the factors influencing the adoption of biological pest control methods by farmers. To identify the factors influencing the adoption of biological pest control methods, using the Wilcoxon one-sample test, the mean of each factor in the questionnaire was compared with the number 3 (the middle of the Likert scale), the results of which are shown in Tables 1 and 2. For any question whose significance level is less than 0.05, the null hypothesis that the median is equal to 3 is rejected (Garren & Davenport, 2022). According to the median and mean that is more or less than 3, it was decided to be less or more than the average limit (3), which is presented in the last column of Table 4. It can be seen that the most effective factors on acceptance are in the attitudinal category and after that economic and social factors were identified as influential factors. Also, educational factors had the least impact. Therefore, by using a questionnaire, the factors influencing the adoption of biological pest control methods by the farmers of the Torshiz area were identified.

3.3.2 Hypothesis 2

To investigate the second hypothesis that economic factors have the greatest impact on the adoption of biological pest control methods, the repeated measures test will be used to compare the average of the four factors. The results of the repeated measures test in Table 5 showed that there is a significant difference between the averages of the four factors. Then the Bonferroni test was performed, the results of which are shown in the last column of Table 5. So, the results showed that based on quadruple tests, there is a significant difference between the 4 investigated variables, and the Bonferroni test revealed that two by two of these factors have a significant difference with each other. Therefore, the most important effective factors are attitudinal factors, followed by economic and then social factors, and educational factors are at the last place. Therefore, the second hypothesis, based on economic factors, has the greatest impact on the acceptance of biological pest control methods, is rejected.

3.3.3 Hypothesis 3

The third hypothesis was that educational and promotional activities are effective in justifying people to accept biological pest control methods. To investigate this hypothesis, it is necessary to compare the educational factors obtained based on the average scores of the relevant questions with the middle of the Likert scale, i.e., 3 (Tanujaya et al., 2022). Considering the normality of this variable, the comparison was made using the one-sample t-test and *P-value* = 0.0001 for all factors. The results showed that the average educational factors are lower than the average (3) (Educational mean = 2.40, Economic mean = 3.82, Social mean = 3.41, and Attitudinal mean = 4.29). Therefore, it is possible to reject hypothesis 3, considering that the average was not in the middle range or more, and concluded that the educational factors had the least impact on adopting biological pest control methods in the Torshiz area.

3.3.4 Hypothesis 4

In the fourth hypothesis, it was said that the age structure and education of farmers are effective in accepting and using biological pest control methods. To investigate this hypothesis, considering that the acceptance and use of biological pest control methods was obtained based on the average scores of related questions and its normality was previously accepted, using the two-way ANOVA test. The effect of age and education on acceptance was investigated, the results of which are shown in Table 6. The results show that age and level of education have no significant effect on the average acceptance and use of biological pest control methods. Therefore, hypothesis 4 is rejected. It is consistent with the study of Hasanimoghaddam et al. (2012) who analyzed the bottlenecks and challenges of the development of biological control technology in the management of rice stem borer control from an economic-social point of view.

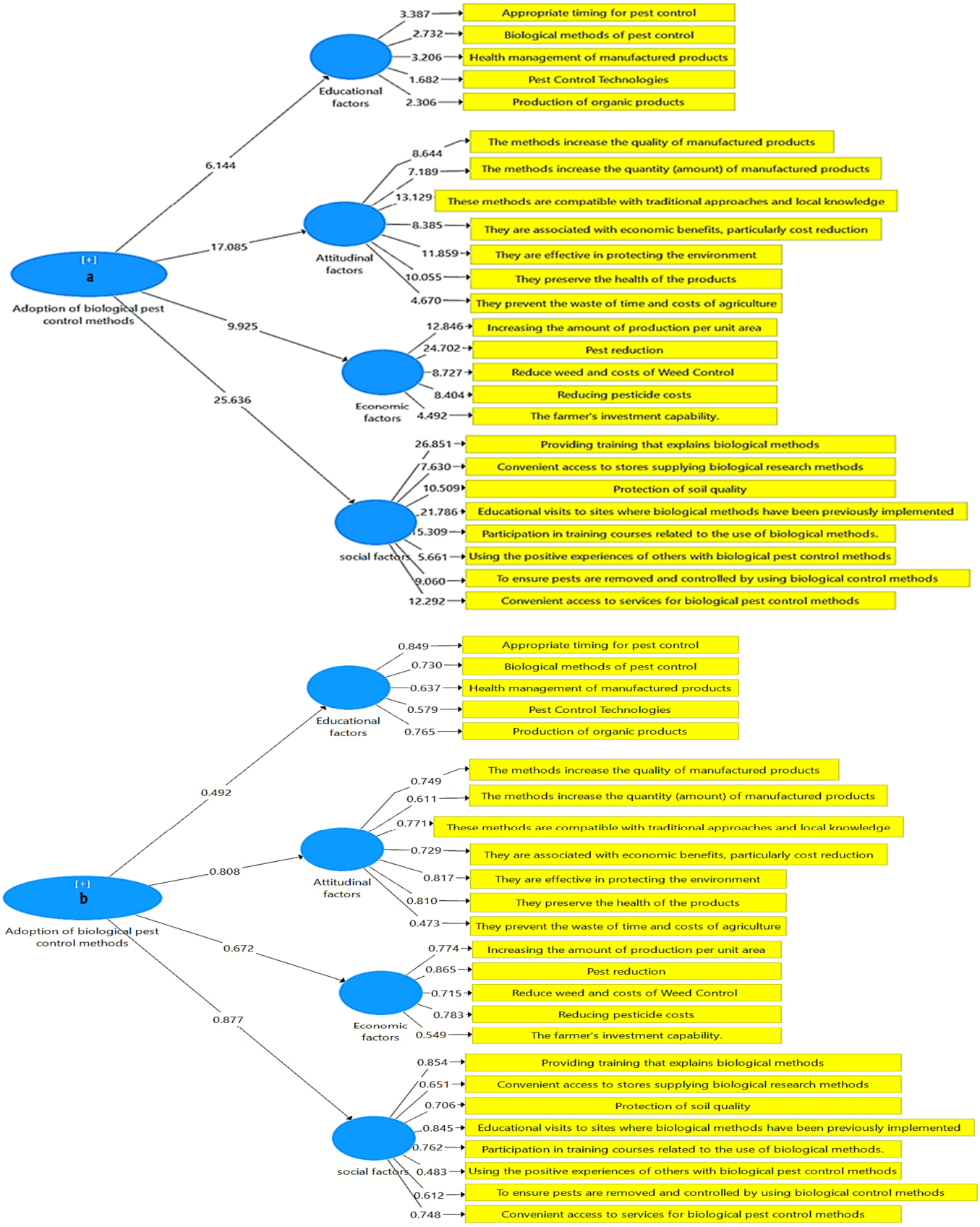

Figure 1. (a): The structural model with t-statistics, (b): path coefficients on paths

Table 4. Investigating the status of factors affecting the adoption of biological pest control methods by farmers in a questionnaire

Category	Investigated factor	Mean	Median	*P-value*	Result
Educational	The methods of biological pest control	2.08	2.00	0.0001	Less than average
	Expertise in utilizing biological methods for pest control	1.65	1.00	0.0001	Less than average
	Technologies related to biological pests' control	1.51	1.00	0.0001	Less than average
	Production of organic products	2.63	3.00	0.002	Less than average
	Appropriate timing for pest control	3.14	3.00	0.294	Close to average
	Biological Pest Control Calendar according to the method and the type of cultivation	1.73	2.00	0.0001	Less than average
	Health management of manufactured products	3.01	3.00	0.987	Close to average
	Planning to grow crops with minimal use of chemical pesticides	3.44	3.00	0.0001	More than average
Economic	Reducing pesticide costs	4.44	5.00	0.0001	More than average
	Reduce labor costs	4.25	4.00	0.0001	More than average
	Reduce weed and its control costs	3.97	4.00	0.0001	More than average
	Pest reduction	4.20	4.00	0.0001	More than average
	Increasing the amount of production per unit area	4.42	5.00	0.0001	More than average
	Diverse cultivation capability	3.00	3.00	0.863	More than average
	The possibility of utilizing adequate banking facilities	3.48	4.00	0.003	More than average
	The low interest rate of bank facilities	3.72	4.00	0.0001	More than average
	Ensure timely provision of facilities and long-term repayment of loans	3.91	5.00	0.0001	More than average
	The farmer's investment capability	3.03	3.00	0.789	Close to average
	The advice of technical experts to use biological pest control methods	3.59	4.00	0.0001	More than average
Social	Providing training that explains biological methods	3.47	4.00	0.001	More than average
	Educational visits to areas with the implementation of biological methods	3.43	3.00	0.001	More than average
	Participation in training courses related to the use of biological methods	3.44	3.00	0.0001	More than average
	Introducing biological methods of pest control on radio and television	3.16	3.00	0.166	Close to average
	Using the positive experiences of others with biological pest control methods	4.33	5.00	0.0001	More than average
	Ensuring the removal and control of pests using biological methods	3.92	4.00	0.0001	More than average
	Introducing the use of biological methods in promotional publications	2.19	2.00	0.0001	Less than average
	Convenient access to services for biological pest control methods	3.35	3.00	0.004	More than average
	The proper treatment of executives and individuals involved in biological processes	3.09	3.00	0.357	Close to average
	Convenient access to stores supplying biological research methods	3.76	4.00	0.0001	More than average
	Advertisements of sellers and suppliers of biological products and services	3.16	3.00	0.192	Close to average
	Protection of soil quality	4.04	4.00	0.0001	More than average
	The level of your risk-taking associated with using these methods	2.96	3.00	0.703	Close to average
Attitudinal	The methods increase the quality of manufactured products	4.75	5.00	0.0001	More than average
	The methods increase the quantity (amount) of manufactured products	4.56	5.00	0.0001	More than average
	They preserve the health of the products	4.42	5.00	0.0001	More than average
	They are effective in protecting the environment	4.27	5.00	0.0001	More than average
	These methods are compatible with traditional approaches and local knowledge	4.19	4.00	0.0001	More than average
	They are associated with economic benefits, particularly cost reduction	4.46	5.00	0.0001	More than average
	The methods increase the income and profit of the family	4.66	5.00	0.0001	More than average
	Farmers have more access to facilities and credits	3.96	4.00	0.0001	More than average
	They cause struggle with traditional thoughts in agriculture	3.67	4.00	0.0001	More than average
	They prevent the waste of time and costs of agriculture	4.25	4.00	0.0001	More than average
	They are technically feasible	4.03	4.00	0.0001	More than average
	Causing greater success in farm management	4.33	5.00	0.0001	More than average

3.4 Strengths and limitations

In most of the reviewed studies, there were gaps in reporting the characteristics of biological control methods and biofertilizers. Most of the reviewed studies had brief descriptions of these methods. These gaps do not allow researchers to provide more specific examples to support the themes and claims. However, all the relevant information was extracted from the reviewed studies and the factors affecting the adoption of biological pest control methods were determined. To encourage farmers to use biological control methods and biofertilizers and reduce excessive use of pesticides and toxic chemical fertilizers, the advantages of using biological methods were highlighted in the Torshiz area. Although we are sure that we have identified and investigated the factors influencing the adoption of biological methods of pest control among farmers in the Torshiz area, our study is not without limitations. First, some farmers were less familiar with biological methods of pest control and this method was not understandable for them. On the other hand, in the application of some methods, there is a need for advanced laboratories complex equipment, and sterile cultivation conditions.

Table 5. Results of repeated measures tests

Test	Amount	Fisher's statistic	df 1	df 2	*P-value*	Effect size	The result based on Bonferroni
Pillai's Trace	0.892	208.938	3.00	76.00	0.0001	0.892	Attitudinal > Economic > Social > Educational
Wilks Lambda	0.108	208.938	3.00	76.00	0.0001	0.892	
Hotelling Trace	8.248	208.938	3.00	76.00	0.0001	0.892	
Roy's Largest Root	8.248	208.938	3.00	76.00	0.0001	0.892	

Table 6. The results of the two-way ANOVA test, investigating the effect of age and education on the acceptance and use of biological pest control methods

Source of change	Sum of squares	df	Mean squared	Fisher's statistic	*P-value*	Effect size
Amount of fixed	250.898	1	250.898	2055.199	0.0001	0.967
Age	0.699	4	0.175	1.431	0.233	0.075
Education level	0.359	3	0.120	0.982	0.406	0.040
Error	8.668	71	0.122	-	-	-
Total	966.984	79	-	-	-	-

4. Conclusion

This research was conducted to investigate farmers' economic, social, educational, and attitudinal factors in accepting biological pest control methods with a descriptive-analytical approach and using questionnaires and fieldwork in the Torshiz area of Khorasan Razavi. The method of figuring to control the pests of all the respondents was using chemical methods. The results showed that the role of technologies related to biological pest control and health management of manufactured products in the education factor had the highest and lowest effect, respectively. The role of reducing pesticide costs and the ability to diverse cultivation capability had the highest and the lowest effect on the economic factor, respectively. The use of the positive experiences of others with biological pest control methods and the introduction of the use of biological methods in promotional publications had the highest and lowest effects for the social factor, respectively. The increase in the quality of manufactured products has the highest impact on the attitudinal factor and the struggle with traditional thoughts in agriculture has the lowest impact. At the confidence level of 0.95 and using the Friedman test, all the components related to all 4 factors did not have the same ranks. The most effective factors in the acceptance of biological pest control methods were in the attitudinal category, followed by economic and social factors. Also, the educational factor had the least impact. According to the ranking of the influential components in four factors, it can be concluded that to increase the quality of manufactured products to accept healthy technologies related to biological control in the Torshiz area, the costs of pesticides should be reduced and taken advantage of the positive experiences of other farmers in using biological methods of pest control.

Authors' Contributions

Somayeh Galdavi: Data curtain; Methodology; Writing. **Fatemeh Ghomanjani:** Data analysis; Methodology. **Farzad Mehrjo:** Methodology; Rewriting-review & editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Ethical considerations

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured of the confidentiality of their information. Participants had the freedom to withdraw from the study at any time, and if desired, the research results would be made available to them. Written consent was obtained from all participants. This study was approved by the Ethics Committee of the University of (Kashmar Higher Education Institute) (Code: GH779/1403/447).

Using artificial intelligence

No artificial intelligence was used in this research.

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