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TOMATO FARMERS' ATTITUDES TOWARD BIOLOGICAL CONTROL IN THE NEWLY RECLAIMED LANDS OF MATROUH GOVERNORATE

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ABSTRACT

This study aimed to identify the personal, social, and economic characteristics of the surveyed tomato farmers, assess their attitudes toward the application of biological control methods, and examine the relationship between selected independent variables and farmers' attitudes toward biological control. The study was conducted in Matrouh Governorate on a random sample of 260 respondents. Data were collected in January 2025 through personal interviews using a questionnaire specifically designed for the study objectives and pre-tested prior to data collection. The results showed that 58.9% of respondents were under 60 years of age and that 82.3% were literate. In addition, 63.8% were fully engaged in agricultural work, 76.2% were smallholders, and 93.5% exhibited low participation in local development organizations. Moreover, 51.5% of the respondents demonstrated a high readiness for agricultural modernization. The attitude scale showed high validity and internal consistency. The findings revealed that 90% of the surveyed farmers held negative attitudes toward biological control, compared with 8.1% neutral attitudes and only 1.9% positive attitudes. All biological control methods were ranked within the negative attitude category, with differences in their relative order. A statistically significant relationship was found only between farmers' attitudes toward biological control and farm size. The study recommends designing and implementing applied extension programs on biological control, with a particular focus on smallholders, relying on field-based training and on-farm demonstrations to enhance farmers' confidence and acceptance of biological control practices within integrated pest management programs.

KEYWORDS: Tomato Farmers; Biological Control; Farmers' Attitudes; Integrated Pest Management (IPM); Agricultural Extension.

1. INTRODUCTION

Tomato (Solanum lycopersicum L.) is one of the most economically and nutritionally important vegetable crops worldwide, particularly in Mediterranean and semi-arid agro-ecosystems. In many developing countries, including Egypt, tomato production has expanded markedly into newly reclaimed lands as part of national strategies aimed at increasing agricultural output, improving food security, and optimizing land and water use. Despite this strategic importance, tomato cultivation in newly reclaimed areas is often associated with complex agronomic and institutional challenges, including high pest pressure, fragile agro-ecosystems, limited farming experience, and relatively weak extension support compared to long-established agricultural regions (Simoglou et al., 2024).

Pest management represents one of the most critical constraints to sustainable tomato production in these newly reclaimed lands. In practice, farmers frequently rely on intensive chemical pesticide use as a rapid and familiar response to pest outbreaks. Although chemical control may provide short-term effectiveness, its excessive and often improper use has been widely linked to pesticide resistance, environmental contamination, adverse human health effects, and rising production costs, in addition to increasing restrictions imposed by domestic and export markets regarding food safety and pesticide residue limits (Pretty & Bharucha, 2015; Parsa et al., 2014; Ivezić et al., 2025). These intertwined challenges underscore the urgent need for alternative pest management strategies that are both environmentally sustainable and economically viable.

Within this context, biological control—whether implemented as a standalone approach or within integrated pest management (IPM) frameworks—has been widely recognized as a cornerstone of sustainable tomato production. Biological control relies on natural enemies, biopesticides, and ecological regulation mechanisms to suppress pest populations while minimizing negative effects on non-target organisms and the environment. Recent studies demonstrate that biological control agents can significantly reduce dependence on chemical pesticides, enhance ecosystem services, and contribute to the long-term stability of pest populations, particularly in greenhouse and open-field tomato systems (Wyckhuys et al., 2025). Empirical evidence from Egypt and comparable agro-ecological contexts further confirms that biological control can be effective under local conditions when properly adapted to prevailing production systems and supported by adequate technical guidance and monitoring (Abd-Elgawad, 2020).

The relevance of biological control is particularly pronounced in tomato cultivation due to the severity of key pests such as the tomato leafminer (Tuta absoluta), which is capable of causing yield losses ranging from 80% to 100% under inadequate management conditions (Desneux et al., 2010). The rapid reproduction, cryptic feeding behavior, and increasing resistance of such pests reduce the long-term effectiveness of chemical control and further emphasize the strategic importance of biologically based and integrated approaches. Nevertheless, despite their proven agronomic and environmental benefits, biological control practices often remain underutilized by farmers, especially in developing and newly reclaimed agricultural areas (Parsa et al., 2014).

A growing body of literature indicates that technical effectiveness alone is insufficient to ensure the adoption of biological control. Instead, farmers' attitudes, perceptions, and beliefs play a decisive role in shaping pest management decisions. Factors such as perceived risk, trust in biological control agents, access to reliable information, previous experience, cost considerations, and the level of institutional and extension support strongly influence farmers' willingness to adopt non-chemical pest management alternatives (Kirui et al., 2023; Constantine et al., 2023). In newly reclaimed lands—where production systems are still evolving and uncertainty is relatively high—these behavioral and cognitive dimensions become particularly influential.

In this regard, recent advances in behavioral and social research have highlighted the value of applying theoretical frameworks such as the Theory of Planned Behavior (TPB) to explain farmers' pest management decisions. Empirical studies on tomato growers demonstrate that attitudes often represent the strongest predictor of behavioral intention, while perceived behavioral control and access to training significantly affect actual practice (Pirmoghani et al., 2024). Moreover, integrating TPB with norm-based approaches, such as the Norm Activation Model, has been shown to enhance the explanatory power of adoption models by emphasizing the role of personal norms and moral obligations in shaping farmers' intentions toward IPM and biological control practices (Rezaei et al., 2019).

In Egypt, adoption challenges are further compounded by limitations within agricultural extension systems. Field-based studies have documented substantial extension knowledge gaps among tomato farmers regarding IPM recommendations, with the highest levels of knowledge need consistently associated with biological control practices (Salama & Amer, 2025). Limited availability of trained extension personnel, inadequate farmer participation in extension program design, and heavy reliance on informal information sources have been identified as key barriers to the effective dissemination and sustained use of biological control technologies, particularly in newly reclaimed areas where extension services tend to be weaker.

Within Matrouh Governorate, empirical evidence reveals a complex and heterogeneous adoption landscape. Research conducted in Al-Hammam Center showed that a considerable proportion of tomato farmers exhibit moderate to high levels of reluctance toward applying biological control methods, driven by factors related to farmers' characteristics, technological requirements, and weaknesses in extension support (Eid 2019،). Conversely, other studies carried out in the same geographical context reported relatively higher adoption levels of biological control against specific pests, such as whitefly, suggesting that farmers' attitudes and adoption behavior vary according to pest type, perceived effectiveness, and experiential learning (ELKadi 2018،). This variation indicates that biological control should not be treated as a uniform package, but rather as a set of practices whose acceptance depends on farmers' perceptions, experience, and the surrounding institutional environment.

In this context, agricultural extension systems play a pivotal mediating role between scientific innovations and farmers' decision-making processes. Extension is no longer viewed solely as a mechanism for technology transfer but as an interactive system that facilitates learning, adaptation, and feedback among farmers, researchers, and policymakers. (El-Ghani & Mansour, 2025; Khamis et al., 2025) Its effectiveness in promoting sustainable innovations such as biological control depends largely on its ability to influence farmers' knowledge structures and attitudes, reduce perceived risks, and enhance confidence in new practices (Pigford et al., 2018).

Accordingly, understanding tomato farmers' attitudes toward biological control is increasingly regarded as a prerequisite for designing effective extension interventions, participatory training programs, and policy instruments that encourage sustainable pest management practices (Wyckhuys et al., 2025). Research on farmers' preferences further suggests that limited ecological knowledge and weak understanding of natural enemy functions represent major barriers to adoption, while targeted extension and experiential learning approaches can significantly improve acceptance and sustained use of biological control strategies (Gumbau et al., 2026).

Within this framework, examining tomato farmers' attitudes toward biological control in the newly reclaimed lands of Matrouh Governorate is both timely and necessary. Such analysis provides critical insights into the behavioral and institutional factors shaping adoption decisions and helps bridge the gap between scientific recommendations and on-farm practices. By identifying prevailing attitudes and their socio-economic and institutional determinants, the present study contributes to the development of more context-specific extension strategies and evidence-based policies aimed at promoting sustainable tomato production systems in newly reclaimed agricultural areas.

1.1. Research Problem

Agricultural development remains a central pillar of socio-economic development in Egypt, given its substantial contribution to national income, employment, and food security. However, sustaining agricultural productivity—particularly in newly reclaimed lands—faces persistent challenges, foremost among them the widespread incidence of agricultural pests that threaten crop yields and quality. Tomato production, despite its strategic importance and comparative advantage in Egypt, is especially vulnerable to pest infestations, which has led farmers to rely heavily on chemical pesticides as a rapid and familiar control option. Although chemical control provides short-term effectiveness, its excessive and unregulated use has resulted in serious environmental, economic, and health consequences, including pesticide resistance, ecological imbalance, contamination of soil and water resources, and increased health risks to farmers and consumers. These drawbacks have intensified the need for safer and more sustainable pest management alternatives. In this context, biological control has emerged as a core component of integrated pest management (IPM), offering an environmentally sound approach that reduces chemical dependence and supports ecological balance.

Despite the proven effectiveness and environmental advantages of biological control methods, their adoption among tomato farmers remains limited and inconsistent, particularly in newly reclaimed agricultural areas. Field observations and prior studies indicate that this limited adoption is not solely a technical issue, but is strongly influenced by farmers' attitudes, perceptions, and socio-economic and institutional conditions, including access to extension services and reliable information (Parsa et al., 2014; Rezaei et al., 2019; Mulugeta et al., 2024). Accordingly, there is a clear research gap concerning the understanding of tomato farmers' attitudes toward biological control and the factors shaping these attitudes in newly reclaimed lands. Addressing this gap is essential for designing effective extension interventions and promoting the sustainable adoption of biological control practices in tomato production systems.

In light of the growing challenges associated with pest management and the increasing call for sustainable agricultural practices, tomato is considered one of the vegetable crops with a comparative advantage in Egypt, as it is cultivated year-round over extensive areas. At the same time, it is among the crops most susceptible to pest infestations and, consequently, among the highest consumers of chemical pesticides. This situation has increased the need to adopt biological control methods as a safe and sustainable alternative or complement, particularly in newly reclaimed areas characterized by environmental sensitivity and a greater need for extension support. Despite the growing importance of biological control, field observations and previous studies indicate a low level of adoption of these methods among tomato growers, as well as variation in their attitudes toward them. This reflects a knowledge, behavioral, and extension gap that warrants systematic investigation and analysis.

Accordingly, the research problem is formulated around addressing the following questions:

1. What are the personal, social, and economic characteristics of the tomato growers under study?
2. What are tomato growers' attitudes toward the application of biological control methods?
3. What personal, social, and economic factors influence farmers' attitudes toward biological control?

1.2. Research Hypotheses

There is a statistically significant relationship between tomato farmers' attitudes toward biological control and selected personal, social, and economic characteristics.

2. METHODOLOGY

2.1. Study Area

El-Hammam District was purposively selected as the study area due to its agricultural importance in Matrouh Governorate. It is the second-largest agricultural district after Sidi Barani, with a cultivated area of approximately 5,280 feddan, representing about 16% of the governorate's total cultivated land (Table 1). The district is characterized by extensive tomato production in newly reclaimed lands, which makes it particularly suitable for examining farmers' attitudes toward biological control.

The study population consisted of tomato farmers in El-Hammam District, from whom a representative sample was selected in line with the objectives of the study.

Table (1): The Total Area in the Matrouh Governorate, Inventory of the Area for Tomatoes In 2024.

District	*The total area*	*Tomatoes*
Elhamam	5280	11927
El Alamein	1465	75
the daba'a	209	40
Matrouh	2300	350
Elnegela	715	40
Sidi Barany	22000	-
Siwa	91	22
Total	**32060**	**12454**

2.2. Study Sample

The research sample was drawn from tomato farmers in El-Hammam District, Matrouh Governorate, where six agricultural associations collectively cultivate 11,927 feddan of tomatoes. The three largest associations in terms of cultivated area were purposively selected, namely: Abu Shebeina Association, with an area of 3,600 feddan and 750 registered tomato farmers; El-Hammam Association, with an area of 350 feddan and 700 tomato farmers; and El-Ameed Association, with an area of 3,300 feddan and 600 tomato farmers. Together, these three associations account for approximately 86.4% of the total area cultivated with tomatoes in El-Hammam District. The total population of tomato farmers in the selected associations amounted to 2,042 farmers.

The sample size was determined based on the total population of 2,042 farmers, using a sampling fraction of 13%, resulting in a sample of 260 respondents. Using the same proportion, farmers were selected through simple random sampling from each association as follows: 97 farmers from Abu Shebeina, 91 farmers from El-Hammam, and 72 farmers from El-Ameed. (Directorate of Agriculture in Matrouh, 2024, unpublished data), as presented in Table (2).

Table No (2): Distribution of the Research Sample Among the Selected Agricultural Associations.

Association name	Area Cultivated with Tomatoes	Number of Farmers	the sample
El-Hamam	3500	700	91
15th of May	802	-	-
El-Ameed	3300	552	72
Abu Shebeina	3600	750	97
Elm Fanoosh	400	-	-
Abna'a Almustaqbal	325	-	-
Total	**11927**	**2042**	**260**

Data collection method and tool: To accomplish the research's goals, a questionnaire was created that contained a number of inquiries about tomato growers' inclinations towards biological control in newly discovered areas and the investigated independent variables. The questionnaire's design took into account how well it connected to the overall framework of the study problem, its goals, and the simplicity of its methodology in light of the respondents' circumstances.

An initial test of the questionnaire was conducted on a sample of 15 farmers from the 15 May Association to verify the clarity and ease of understanding of the phrases by the respondents. The information was gathered from the respondents in-person throughout the month of January 2025.

Quantitative data processing:

First: the independent variables:

1. **Age:** Age was measured as the respondent's actual age in completed years at the time of data collection.
2. **Educational Level**: referred to the respondent's formal education and was measured by assigning scores based on years of schooling: illiterate (0), able to read and write (4), primary (6), preparatory (9), secondary or equivalent (12), post-secondary (14), and bachelor's degree or equivalent (16).
3. **Dedication to agricultural work:** It refers to how much the respondent's level of commitment to farming activities and was scored as fully devoted (3), partially devoted (2), or not devoted (1).
4. **Family Members Working in Agriculture:** It refers to the total number of household members engaged in agricultural work and was measured as a raw count.
5. **Agricultural holding:** Agricultural Holding Size represented the total cultivated area farmed by the respondent, regardless of tenure type, and was measured in qerate (1/24 feddan).
6. **Participation in local development organizations:** was measured based on membership level and attendance in local organizations, with scores reflecting the respondent's degree of participation.
7. **Readiness for Agricultural Modernization** reflected the respondent's willingness to adopt new agricultural practices and was measured using a weighted scale (2 = implement immediately, 1 = wait, 0 = not implement).

Second: Dependent Variable

Degree of Tomato Farmers' Attitudes Toward Biological Control

This variable refers to the extent to which the surveyed tomato farmers express favorable, unfavorable, or neutral responses toward the biological control practices presented to them, as well as their inclination to adopt or reject biological control methods.

2.3. Likert's Method Was Used to Measure Trends

A three-point Likert scale was used to measure tomato farmers' attitudes toward biological control. The scale consisted of 17 statements reflecting farmers' favorable, unfavorable, or neutral positions toward several biological control methods, including pathogenic bacteria, pathogenic nematodes, growth regulators and molting hormones, and the sterilization of male insects. Responses were measured on three categories: agree (3 points), neutral (2 points), and disagree (1 point) for positively worded statements, with the scoring reversed for negatively worded statements. Based on the theoretical range, the maximum possible score was 255 points and the minimum was 85 points, yielding a range of 170 points. Accordingly, attitudes were classified into three levels: negative (less than 142 points), neutral (from 142 to less than 199 points), and positive (199 points or more). In addition, mean attitude scores were calculated for each biological control method by dividing the obtained score by the maximum possible score and converting the result into percentages. Based on these percentages, attitude levels were determined, and the studied methods were ranked according to the percentage of the mean attitude scores.

2.4. The Reliability and Validity of the Scale of the Surveyed Farmers' Attitudes Toward Biological Control

To assess the reliability of the scale, the split-half method was used to calculate the reliability coefficient. The correlation coefficient between the two halves of the scale was 0.531. A statistical correction was then applied using the Spearman–Brown formula, resulting in a reliability coefficient of 0.6341, which indicates an acceptable level of scale reliability.

To verify the validity of the scale, the coefficient of self-validity was calculated by taking the square root of the reliability coefficient, yielding a value of 0.7963, which reflects a high level of scale validity. In addition, the statistical validity coefficient was calculated using the statistical validity measurement equation as proposed by Motobol, as cited in Nafisa El-Hawary (2002, p. 47).

$$RS = \frac{nr}{1+(n-1)r}$$

where:

Rs = validity coefficient **R** = mean correlation coefficient between the scale items and the total scale score **N** = number of scale items

The results indicated that the statistical validity coefficient reached 0.931, which is a high value reflecting strong scale validity. To examine the internal consistency of the scale dimensions, simple correlation coefficients were calculated between each item and the total scale score. The results showed that all correlation coefficients were statistically significant at the 0.05 and 0.01 levels.

2.5. Statistical Analysis

SPSS program was used to analyze the study's data using a tabular display with frequencies, percentages, means, standard deviations, and a simple correlation coefficient.

3. RESULTS

First: Characteristics of the studied farmers:

1. **The age:** The study's findings, which are presented in Table 3, revealed that the variable's true range was between (28 and 75 years), with an arithmetic mean of (50.4 years) and a standard deviation of (10.003), The data in the same table show that 58.9% of the total respondents are under 60 years old, a stage characterized by mental and intellectual maturity. This is reflected in the ability of these respondents and the speed of their acceptance of the new agricultural ideas. The respondents were divided into three age categories: the first (less than 44 years), the second from (44 to less than 60 years), and the third (more than 60 years).
2. **The degree of education of the respondent:** The results of Table (3) regarding the respondent's level of education revealed that the variable's real range was between 0 and 16 points, with a mean of 6.51 points and a standard deviation of (4.944), Three groups of respondents were identified: those who were illiterate, those who could read and write, and those who had a degree. The data in the same table indicate that 17.7% of the total respondents are illiterate, while it was found that 36.5% of them know how to read and write, and that 45.8% of them have a high qualification, meaning that only 82.3% of the total respondents were able to read and write, and this shows the high level of education, which indicates their ease of acceptance of new agricultural innovations.
3. **Dedication to agricultural work:** A person's performance, experience, and interests are influenced by their commitment to their profession, and their commitment to agriculture increases their interest in their land and their desire to master it and to achieve the largest gains. Hence, everything new is implemented in an effort to boost output. The study's findings, which are presented in Table 3, revealed that this variable's real range is between (1-3 points), with a mean of (2.63 points) and a standard deviation of (0.499). The respondents were categorized into three groups: full-time, part-time, and unavailable. According to the same table's findings, 63.8% of all respondents are entirely dedicated to agricultural work, these findings show a high proportion of farmers who are entirely committed to their agricultural profession, which may be a sign of their extensive background in related disciplines.
4. **The total number of family members**

working in agriculture: The study's findings, which are presented in Table 3, revealed that the variable's true range was between 0 and 9, with a mean of 2.48 and a standard deviation of (1.978). Three groups of respondents were created: the first group included only four people, the second group included six to eight people, and the third group included more than eight people (more than 6 individuals), These results show that more than half of respondents have a small number working in agriculture, and it is necessary to re-educate the educated people and community members that working in the agricultural profession does not require a college degree. The results of the same table show that 53.1% of the total respondents have less than four people working in agriculture. It lowers the standing of persons with scientific qualification, as they are more knowledgeable and aware of the advancements in the field of implants.

5. **Agricultural holding:** The study's findings, which are presented in Table 3, revealed that this variable's real range was between (4-216 acres), 59.55 acres is average, and the standard deviation is (68.749), According to the actual range, the respondents were split into three groups: those with small holdings (less than 72 acres), those with medium holdings (between 72 and less than 120 acres), and those with large holdings (120 acres and more). According to the data in the same table, 76.2% of all respondents have small holdings (less than 3 acres), This suggests a significant fragmentation of holdings, which has a negative impact on living standards and makes it difficult to introduce certain agricultural innovations that call for large agricultural areas. As a result, extension centers must step up their efforts to transfer these innovations in light of this holdings fragmentation.
6. **Participation in local development organizations:** The study's findings, which are presented in Table 3, revealed that this variable's real range was between (0-14 points), With a standard deviation of and a mean of 0.52 points (1.857), Three categories of respondents—low involvement (less than 5 points), medium participation (between 5 and less than 10 points), and high participation—were used to categories the respondents (10 points and more). According to the results of the same table, only 93.5% of the respondents overall participated in local development organizations. This finding suggests that these organizations are ineffective at enticing farmers to take part in their activities, which is reflected in the speeding up of the development process.
7. **Getting ready for the modernization of agriculture:** The degree to which a person is prepared for agricultural modernization influences how quickly and easily innovations are adopted. The study's findings, which are presented in Table 3, revealed that this variable's real range was between (6-12 points), With a standard deviation of and a mean of 9.1 points (2.762), The respondents were separated into three groups: those with a low level of ready for agricultural modernization (less than 8 points), those with a medium level of readiness (from 8 to less than 10 points), and those with a high level of readiness (10 points or more). According to the results of the same table, 51.5% of all respondents expressed a high level of willingness and ready to modernize agriculture.

Table (3): Distribution of the Surveyed Farmers According to Their Characteristics.

Properties	Total no. of respondents		Properties	Total no. of respondents	
	F	%		F	%
1. Age			**1. The total number of family members working in agriculture:**		
- less than 44 years	74	28.8	- *Less than 4 individuals*	138	53.1
- 44 to less than 60 years old	79	30.4	- *From 4 to 6 individuals*	75	28.8
- More than 60 years old	107	41.1	- *more than 6 individuals*	47	18.1
2. The degree of education			**2. Agricultural holding:**		
- Illiterate	46	17.7	- *Small holdings (less than 72 acres)*	198	76.2
- Reads and writes	95	36.5	- *Medium holdings (72 to less than 120 acres).*	38	14.6
- Graduated from elementary school	22	8.5	- *Large holdings (120 acres and more)*	24	9.2
- Graduated with high school	31	11.9	**3. Participation in local development organizations:**		

- Middle Certification	32	12.3	- *Low participation (Less than 5 points)*	243	93.5
- Hold a qualification above	13	5	- *Medium participation (5 to less than 10 points)*	11	4.3
- Holds a higher qualification	21	8.1	- *High participation (10 points and more)*	6	2.2
3. Dedication to agricultural work			**4. Getting ready for the modernization of agriculture:**		
- *Dedicated*	166	63.8	• *Low degree of readiness (less than 8 points)*	60	23.1
- *Part-time*	92	35.4	• *Medium readiness (8 to less than 10 points)*	66	25.4
- *Unavailable*	2	0.8	• *High degree of readiness (10 points or more)*	134	51.5

Field data 2025

Second: Degree of Tomato Farmers' Attitudes Toward Biological Control

The results presented in Table (4) indicate that the vast majority of the surveyed tomato farmers (90%) exhibited negative attitudes toward biological control, reflecting a generally low level of acceptance of these practices among farmers in the study area. This predominance of negative attitudes suggests that biological control is still perceived as unfamiliar, risky, or ineffective compared to conventional chemical control methods, which are often viewed as faster and more reliable in addressing pest outbreaks.

In contrast, only a small proportion of farmers demonstrated neutral (8.1%) or positive (1.9%) attitudes toward biological control. The limited share of farmers with positive attitudes indicates that successful adoption and favorable perceptions of biological control remain restricted to a very narrow segment of growers, likely those with greater exposure to extension services, prior experience with biological practices, or higher awareness of their environmental and health benefits. Meanwhile, the presence of neutral attitudes may reflect uncertainty or insufficient information, suggesting that some farmers neither fully reject nor actively support biological control due to a lack of practical knowledge or confidence in its outcomes.

These findings highlight a substantial attitudinal barrier to the adoption of biological control among tomato farmers. They underscore the critical need for targeted extension and training programs that focus on improving farmers' understanding of biological control principles, demonstrating their effectiveness under local conditions, and reducing perceived risks associated with their application. Without addressing these attitudinal constraints, the widespread adoption of biological control within integrated pest management programs is likely to remain limited.

Table (4): Distribution of the Surveyed Farmers According to Their Degree of Attitude Toward Biological Control.

Tendency degree	The total number of farmers surveyed	
	F	%
Negative orientation (less than 142 points)	234	90
Neutral orientation (142 to less than 199 points)	21	8.1
Positive orientation (from 199 points or more)	5	1.9
Total	260	100

Field data 2025

Third: Degree of the surveyed farmers' attitudes toward each biological control method

The results in Table (5) indicate that farmers' attitudes toward all biological control methods were negative. The highest-ranked attitude was toward the use of pathogenic nematodes, with a mean score of 1.50 and a percentage of 50%. This was followed by sexual attractant pheromones, which ranked second with a mean of 1.41 and a percentage of 47%. The third rank was occupied by the sterilization of male insects, with a mean of 1.32 and a percentage of 44%. Pathogenic bacteria ranked fourth, with a mean of 1.26 and a percentage of 42%. In fifth place came mating disruption pheromones, with a mean of 1.15 and a percentage of 38.3%, while the last rank recorded a mean of 1.15 and a percentage of 37.3%.

These results clearly demonstrate that negative perceptions prevailed across all studied biological control methods, albeit with varying degrees of acceptance among farmers.

Table (5): Distribution of the Surveyed Farmers According to Their Attitudes Toward Biological Control Methods.

biological control methods	Average	Average %	Tendency
1. *pathogenic nematode*	1.50	50	negative
2. *Growth regulators and releasing hormones*	1.41	47	negative
3. *the sterilization of male insects*	1.32	44	negative
4. *pathogenic bacteria*	1.26	42	negative
5. *the pheromone of interference*	1.15	38.3	negative
6. *the pheromone of sexual attractants*	1.12	37.3	negative

Field data 2025

Fourth: Relationship between the studied independent variables and the surveyed farmers' attitudes toward biological control

The results presented in Table (6) revealed a statistically significant relationship between farmers' attitudes toward biological control and only one independent variable, namely agricultural holding size. The simple correlation coefficient for this relationship was 0.190, which is statistically significant at the 0.05 level. Accordingly, the alternative hypothesis stating that "there is a significant correlation between agricultural holding size and the surveyed farmers' attitudes toward biological control" was accepted.

In contrast, no statistically significant relationships were found between farmers' attitudes toward biological control and the remaining independent variables. The calculated simple correlation coefficients for these variables were lower than their corresponding tabulated values at the 0.05 significance level, indicating the absence of significant associations.

Table (6): The Correlation Between the Independent Variables and the Attitude of the Surveyed Farmers Towards Biological Control.

independent variables	Simple correlation coefficient values
1. *age*	0.127
2. *Educational level*	- 0.079
3. *Dedication to agricultural work*	0.04
4. *The total number of family members working in agriculture*	0.047
5. *agricultural holding*	0.190*
6. *Participation in local development organizations*	0.071
7. *Getting ready for the modernization of agriculture*	0.029

***The Correlation Coefficient Is Significant at the Level (0.05)**
Tabular Value of R =0.175

4. DISCUSSION

The findings of this study provide important insights into tomato farmers' attitudes toward biological control in the newly reclaimed lands of Matrouh Governorate and contribute to the growing body of literature emphasizing the behavioral and institutional dimensions of sustainable pest management. The predominance of negative attitudes toward biological control among the surveyed farmers represents a critical constraint to the adoption of environmentally sound pest management practices, despite their proven technical effectiveness. Accordingly, the result showing that 90% of farmers held negative attitudes toward biological control aligns closely with previous empirical studies conducted in similar contexts. For instance, Eid (2019) reported a high level of reluctance among tomato farmers in El-Hammam Center toward applying biological control methods, attributing this resistance to limited awareness, lack of practical experience, and perceived uncertainty regarding effectiveness. Similarly, Parsa et al. (2014) emphasized that adoption barriers to integrated pest management and biological control in developing countries are rarely technical in nature, but are instead deeply rooted in farmers' perceptions, risk aversion, and institutional shortcomings.

The very limited proportion of farmers expressing positive attitudes (1.9%) suggests that favorable perceptions of biological control are confined to a narrow group of growers, likely those with prior exposure to extension services or hands-on experience. This interpretation is consistent with Constantine et al. (2023), who demonstrated that farmers' positive attitudes toward biological control are strongly associated with experiential learning and access to credible technical support. The presence of a small segment of farmers with neutral attitudes further indicates a state of uncertainty rather than outright rejection, implying potential responsiveness to well-designed extension interventions.

When examining attitudes toward individual biological control methods, the uniformly negative perceptions across all techniques—albeit with varying degrees—underscore that farmers do not perceive biological control as a single homogeneous practice. The relatively higher ranking of pathogenic nematodes and pheromone-based methods suggests that familiarity and perceived tangibility play a role in shaping attitudes, a finding that echoes ELKadi (2018), who observed higher acceptance of biological control against specific pests such as whitefly when farmers perceived visible and rapid effects. Conversely, lower-ranked methods such as mating disruption pheromones may suffer from abstract mechanisms that are less easily understood by farmers, reinforcing the importance of effective communication and demonstration.

The statistically significant relationship between farmers' attitudes and agricultural holding size provides further insight into adoption dynamics. Larger holdings may allow greater flexibility to experiment with alternative pest management strategies and absorb potential risks, whereas smallholders—who constitute the majority of respondents—tend to prioritize immediate and predictable outcomes, often favoring chemical control. This finding is consistent with Rezaei et al. (2019), who found that perceived behavioral control and economic capacity significantly influence farmers' intentions to adopt IPM practices. The absence of significant relationships with other socio-demographic variables suggests that structural and economic constraints may outweigh individual characteristics in shaping attitudes toward biological control. Taken together, these findings reinforce the argument that improving farmers' attitudes toward biological control requires more than disseminating technical recommendations. As emphasized by Pigford et al. (2018), extension systems must move beyond linear technology transfer and adopt interactive, learning-oriented approaches that reduce perceived risk and build confidence. Field demonstrations, participatory trials, and continuous technical support are particularly crucial in newly reclaimed lands, where farmers face higher uncertainty and weaker institutional backing. Moreover, strengthening extension knowledge related to biological control, as highlighted by Salama and Amer (2025), is essential to bridge the gap between scientific knowledge and on-farm decision-making. Overall, the discussion confirms that the limited adoption of biological control among tomato farmers in Matrouh Governorate is primarily an attitudinal and institutional challenge rather than a technological one. Addressing these constraints through targeted, context-specific extension strategies is a prerequisite for enhancing the role of biological control within integrated pest management programs and promoting sustainable tomato production in newly reclaimed agricultural areas.

5. RECOMMENDATIONS

Based on the study findings, the following recommendations are proposed:

1. **Strengthening extension programs** focused on biological control through applied, field-based training and on-farm demonstrations to improve farmers' awareness, confidence, and practical skills.
2. **Targeting smallholders** in newly reclaimed lands with tailored extension interventions that address their specific constraints and reduce perceived risks associated with biological control practices.
3. **Enhancing extension capacity** by training extension agents on biological control methods and effective communication strategies to better translate scientific knowledge into practical, farmer-friendly messages.
4. **Promoting participatory approaches**, such as farmer field schools and pilot trials, to facilitate experiential learning and encourage positive attitudes toward biological control.
5. **Improving institutional support**, including the availability of biological control inputs and technical follow-up, to create an enabling environment for wider adoption within integrated pest management programs.

Data availability: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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