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Adoption of Integrated Pest Management in Ghanaian Tomato Agriculture: What Are the Key Determinants?

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ABSTRACT

Integrated pest management (IPM) offers an effective and environmentally sensitive approach to pest control, reducing reliance on chemical pesticides. However, its adoption among tomato farmers has been slow, with excessive chemical pesticides causing resistance, environmental pollution, and biodiversity loss. This study examines the factors influencing IPM adoption among tomato farmers in Offinso North, Ghana. Data were collected from 388 farmers using a structured questionnaire. Results indicated that access to extension services, farming experience, the number of workers, and years of formal education significantly influenced the adoption of various IPM methods. Access to extension services was critical across all methods, while farming experience and the number of workers were key for cultural

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and mechanical practices. Education enhanced the adoption of mechanical techniques. These findings highlight the importance of targeted training programs and access to resources to improve IPM knowledge and adoption among farmers. Policymakers should focus on farmer education and extension services to enhance sustainable pest management by providing technical support, facilitating access to IPM inputs such as organic fertilisers and biological control agents, and guidance in implementation. Other interventions may include enhancing farmer groups' access to low-interest finance or credit facilities.

Keywords: Adoption, Tomato, Determinants, Integrated Pest Management.

1. INTRODUCTION

Tomatoes remain a significant global vegetable due to their growing commercial and dietary importance. They are considered a valuable source of essential vitamins, such as A, B, and C. Regarding agricultural significance, tomatoes are ranked second to potatoes (Quinet *et al.,* 2019). They are cultivated in several Ghana regions and hold a prominent position within the culinary landscape, serving as a vital ingredient in numerous traditional dishes. The production of tomatoes substantially enhances Ghana's livelihoods (Gerszberg *et al.,* 2015).

Integrated pest management (IPM) is a comprehensive approach that prioritises implementing sustainable cultural, mechanical, biological, and chemical control methods to address pest issues. It involves the utilisation of the most discerning pesticide that effectively fulfils its purpose while minimising harm to other organisms and preserving the quality of air, soil, and water (Dreistadt *et al*., 2016). IPM involves the judicious use of pesticides, which are employed selectively and in conjunction with other strategies to achieve enhanced and sustainable control (Karlsson *et al*., 2020). Pesticides are selected and applied to minimise potential risks to human health, non-target creatures, and the environment (Damalas *et al*., 2011). Its primary objective is to minimise risks to human health and the environment while emphasising long-term prevention strategies (Rai *et al*., 2012; Robinson *et al*., 2010; Kelley *et al*., 2010). It also utilises scientific research to explore effective methodologies that can help farmers reduce their reliance on frequent pesticide application (Kabir *et al*., 2015; Uwagboe *et al*., 2016).

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Biological control involves utilising naturally occurring organisms such as predators, parasites, diseases, and competitors to manage and mitigate the negative impacts caused by pests. Cultural controls refer to practices that aim to mitigate pests' establishment, reproduction, dissemination, and survival. Mechanical control methods encompass several techniques that directly eliminate pests, prevent their entry, or render the surrounding environment inhospitable to their survival. Rodent traps serve as a representative instance of mechanical control measures. Chemical control involves applying pesticides to manage pests (Flint *et al*., 1998; Uwagboe *et al*., 2016).

Implementing IPM practices has been found to enhance agricultural productivity and promote safety in crop production (Dreistadt *et al*., 2001). It has garnered significant acceptance throughout several agricultural systems, encompassing the cultivation of tomatoes (Dreistadt *et al*., 2016; Karlsson *et al*., 2020). A range of factors influences the adoption of IPM among tomato farmers. They include economic considerations (cost-effectiveness, resource availability, and information accessibility), environmental issues (potential repercussions on human health and the environment), and social factors (farmer attitudes towards IPM). Farmers must take into account economic factors while making decisions about whether to implement IPM practices.

Furthermore, the accessibility of resources, including manpower, equipment, and materials, might impact a farmer's inclination to embrace IPM strategies. The availability of information about IPM might significantly influence a farmer's decision to adopt such practices. Adopting IPM among tomato farmers is influenced by environmental concerns, which are considered significant (Rezaei *et al*., 2020).

Every year, pests in the form of insects inflict damage on crops, including tomatoes, on a global scale (Riaz *et al*., 2021). Tomato producers extensively employ agrochemicals to eradicate pests, often without considering the detrimental environmental consequences associated with their usage. Hence, implementing Integrated Pest Management (IPM) holds significant potential to enhance the sustainability, productivity, and environmental integrity of tomato agriculture in Ghana. However, despite the recognised benefits of IPM, its adoption among Ghanaian tomato farmers remains variable, and they have predominantly focused on the chemical components of pest control. This presents a critical challenge to the agricultural sector, as conventional pesticide-dependent practices continue to pose risks to human health, the environment, and food security. To address this issue effectively and promote the broader uptake of IPM, it is imperative to investigate and understand the multifaceted factors influencing its adoption in Ghanaian tomato farming.

Previous research has commonly employed linear, log-linear, or semi-logarithmic regression equations to conduct empirical examinations on the factors influencing the adoption of innovations. Feder (1993) used the ordinary least squares (OLS) method. In their study, Kihoro *et al*. (2021) employed the binary logistic regression model to examine the impact of individual independent variables on the likelihood of adopting IPM in Kenya. Isham (2002) used a probit model to examine the adoption patterns in Tanzania. In Mbata (2001), a multivariate probit model was employed to assess the factors influencing the adoption of animal traction in Lesotho. Hasan (2017) analysed the factors affecting integrated pest management adoption and pesticide use in Kenya. The Tobit model was used by Bisanda *et al*. (1998) to examine the utilisation level when adoption takes place. This research seeks to comprehensively identify and analyse these factors, providing valuable insights and evidence-based recommendations to guide policy, extension services, and agricultural practices for Ghana's more sustainable and resilient tomato agriculture sector. Firstly, it seeks to evaluate the perception of tomato farmers regarding IPM practices. Secondly, it assesses the extent to which farmers have adopted IPM practices in their tomato farming activities. Thirdly, the study determines the factors influencing tomato farmers' decision to adopt IPM practices. It also examines farmers' perceptions of the effects of adopting IPM. Lastly, the study ascertains the challenges farmers face in adopting IPM.

2. METHODOLOGY

2.1. Study Area

The study was conducted at the Offinso North District in the Ashanti Region of Ghana. The district is located in the northwestern part of the region and covers an area of 1,845 square kilometres. It lies between latitudes 6°30'N and 7°00'N and longitudes 1°30'W and 2°00'W. It is bordered to the north by Techiman Municipal District, to the east by Sekyere East District, to the south by Sekyere West District, and to the west by Tano North Municipal District. The terrain of Offinso North District is mostly flat, with some hills in the western part of the district. The rainfall pattern in the district is characterised by two distinct rainy seasons. The first season begins in April and ends in July, while the second season starts in September and ends in November.

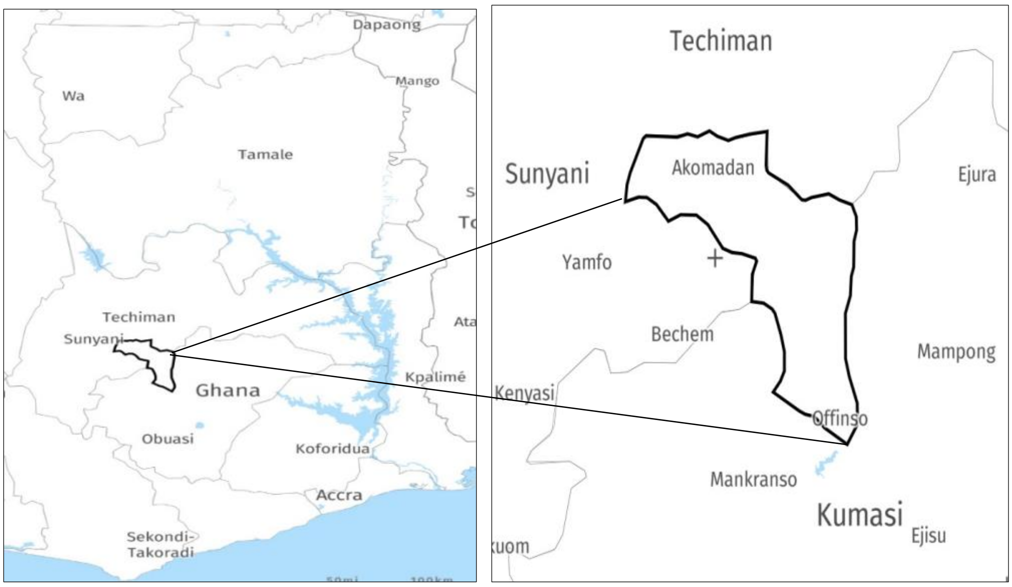

FIGURE 1: Study Area

2.2. Research Design, Population, Sample Size and Sampling

This study was a cross-sectional study. The study population included all tomato farmers in the Offinso North district who had been trained in IPM practices. Using Yamane's (1967) sample size formula, a sample of 388 tomato farmers was selected for the study. A multi-stage sampling technique was used in this study. In the first stage, the purposive sampling technique was used to select the district. This was because the Offinso North District is one of the highest tomato-growing areas in Ghana. In the second stage, five out of 97 communities from the Offinso North District were purposively selected due to farmers' exposure to IPM training and workshops. The selected communities were Akomadan, Afrancho, Asuoso, Nkenkaasu and Nsenua. A simple random technique was employed in the third stage of the sampling procedure to select farmers from each community, giving equal probabilities for each farmer being selected. In all, 388 tomato farmers were sampled, with 159 from Akomadan, 38 from Afrancho, 103 from Nkenkaasu, 16 from Asuoso, and 72 from Nsenua.

2.3. Data Collection

The study utilised primary and secondary data. Primary data was collected through a structured questionnaire via a face-to-face interview approach. Secondary data was sourced from the review of IPM-related literature. Questionnaire validity was confirmed by a panel of

IPM experts, which comprised staff from the Ministry of Food and Agriculture, extension officers, and academics from the Kwame Nkrumah University of Science and Technology. The calculated Cronbach's alpha of 0.81 also indicated the reliability of the designed instrument.

2.4. Analytical Framework

The perception of tomato farmers on IPM was analysed using descriptive statistics. A five-point Likert scale was employed, from 1= strongly disagree, 2= disagree, 3=neutral, 4=agree, and 5=strongly agree. The perception index was calculated by using the formula:

$$P = (\Sigma (Fi \times Mi)) / N$$

Where: P = Perception index, Σ = Summation of all the mean scores, Fi = Frequency of the ith statement, Mi = Numerical value assigned to the ith statement on the three-point Likert scale, N = Total number of statements. The farmer's adoption of integrated pest management (IPM) was also analysed using descriptive statistics such as means and standard deviations. A five-point Likert scale ranging from (1=never, 2=rarely, 3=sometimes, 4=often, 5=always) was used to achieve this objective. Farmers perceived challenges in adopting IPM strategies, which were also ascertained using Kendall's coefficient of concordance.

The study also examines the many factors that have an influence on the adoption of IPM among tomato farmers, drawing insights from studies such as (Robinson *et al.*, 2010; Damalas *et al.*, 2011; Rai *et al.*, 2012; Dreistadt *et al.*, 2016; Karlsson *et al.*, 2020) through the utilisation of the Multivariate Probit Model (MPV). The binary probit model, which restricts values between zero and one, was unsuitable for this investigation due to several dependent variables. In this particular context, it should be noted that Integrated Pest Management (IPM) does not constitute a singular technology that can be readily adopted or rejected by farmers at their discretion. Instead, it comprises a collection of four distinct technologies: chemical, biological, cultural, and mechanical/physical. Therefore, farmers can select from a diverse range of IPM practices and may exhibit significant disparities in adoption. In this particular scenario, adoption does not possess a mutually exclusive nature. As an illustration, one farmer may have chosen to implement the technique of staking. In contrast, another farmer may have opted to incorporate bio-pesticides in their agricultural operations. In the context of this research, it is more suitable to employ the multivariate probit model to examine the adoption phenomenon (Ntow *et al.*, 2023).

To assess the adoption decision behaviour of the farmers and the possibility of simultaneous adoption of multiple IPS methods, the MVP as; $y^*i = xi\, \beta + \mu i$ (1) where, y^*i is an N×1 vector of latent variables faced by the ith farmer in the study area (i=1, 2, …, n). xi is a matrix of N×K for each observation. The vector of unknown parameters β has dimensions K×1 to capture the coefficients associated with each independent. At the same time, the error term μi is structured as an N×1 vector to account for the unobserved random influences faced by the ith farmer in the study area.

Model (1) also becomes a system of m equations (m=1, 2, 3), i.e., $y^*1i = xi\, \beta 1 + \mu 1i$ where, $y1i = 1$ if $y^*1i > 0$; 0 otherwise (2a) $y^*2i = xi\, \beta 2 + \mu 2i$ where, $y2i = 1$ if $y^*2i > 0$; 0 otherwise (2b) $y^*3i = xi\, \beta 3 + \mu 3i$ where, $y3i = 1$ if $y^*3i > 0$; 0 otherwise (2c) $[\mu 1, \mu 2, \mu 3] \sim \Phi 3\ [(0, 1), \delta 12, \delta 13, \delta 23]$, where $\delta 12, \delta 13, \delta 23 \in [-1, 1]$. Whereas, Φ3 is a multivariate standard normal distribution with correlation, δ12 , δ13 , δ23 is the correlation between μ1 , μ2 , and μ3 . The socio-economic factors influencing farmers' adoption of integrated pest management include sex, marital status, farm size, religion, and age.

3. RESULTS AND DISCUSSION

3.1. Socio-Demographic Characteristics of Tomato Farmers

From Table 1, the average age of the respondents is 42 years, with the youngest being 21 and the oldest age being 62 years. The average years of formal education is five years, the minimum is zero (0), and the maximum is 15 years. The average number of dependents of a farmer was four. On average, tomato farmers cultivate two acres of land, with the least being one acre and the highest being 14 acres. The average number of workers of the respondents is seven. The average years of experience of the tomato farmers is 13 years, with the least being one year and the highest being 40 years. The average number of tomato farms of the tomato farmers is one (1) tomato farm with a minimum of one (1) and a maximum of five (5) farms dedicated to tomato production. The results show 58% male respondents and 42% female farmers. The majority of the respondents identified as Christians (68%), married (50%), hire their land for cultivation (41%), use hired labour (58%), are full-time tomato farmers (81%),

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did not have access to extension services (98%), did not have access to credit facilities (99%) and were not members of any farm group (66%).

TABLE 1: Socio-Demographic Characteristics of Tomato Farmers

Continuous Variable	Min.	Max.	Mean	Std. Dev.
Age	21	62	42	8.88
Years of formal education	0	15	5	3.63
Number of dependents	0	15	4	2.91
Farm size	1	14	2	1.43
Number of workers	1	30	7	3.93
Number of tomato farms	1	5	1	0.73
Farming experience	1	40	13	9.52
Categorical variables	Frequency		Percentage (%)	
Sex				
Female	163		42	
Male	225		58	
Religion				
Christianity	264		68	
Islamic	85		21	
Traditionalist	39		10	
Marital Status				
Divorced	33		9	
Married	194		50	
Single	105		27	
Widowed	56		14	
Land ownership type				
Hired	158		41	
Joint venture family	108		28	
Own	122		31	
Type of workers				
Both family and hired	36		9	
Family	126		33	

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Hired	226	58
Occupational Status		
Full-time tomato farmer	315	81
Part-time tomato farmer	73	19
Access to extension services		
No	382	98
Yes	6	2
Access to formal credit		
No	386	99
Yes	2	1
Member of any farmer group		
No	255	66
Yes	133	34

3.2. Farmers' Perception of Integrated Pest Management

In a survey assessing farmers' perceptions of Integrated Pest Management (IPM), several key findings emerged based on mean scores, as presented in Table 2. Respondents strongly agreed with the statement that "IPM is a method of controlling pests using a combination of biological, cultural, physical, and chemical tools" with a mean score of 4.44. They also held a similar level of agreement with the idea that "I am aware of government policies and incentives that support the adoption of IPM practices in agriculture" (Mean=3.63) and "I feel confident in my ability to identify and monitor pest populations in my crops as part of IPM" (Mean=3.70). However, regarding the ease of implementing IPM techniques on their farms, the respondents expressed disagreement, with a mean score of 2.10. They also disagreed with their likelihood of recommending IPM practices to other farmers in their community, with a mean score of 2.47.

The overall mean score of 2.41 for farmers' perception of IPM suggests that farmers generally do not agree with the perception statement and, thus, have a low level of awareness and knowledge. This observation aligns with previous research, such as the study conducted by Owusu *et al*. (2019), which reported a similar lack of awareness and knowledge about IPM among tomato farmers in the Central Region of Ghana. The findings indicate that many farmers are unfamiliar with IPM practices and have a limited understanding of IPM practices.

TABLE 2: Farmers' Perception of Integrated Pest Management (IPM)

Perceptions	S. D F (%)	D F (%)	N F (%)	A F (%)	S. A F (%)	Mean	S. D
IPM is a method of controlling pests using a combination of biological, cultural, physical, and chemical tools.	8 (2)	71 (18)	23 (6)	7 (2)	279 (72)	4.44	0.850
I find it easy to implement IPM techniques on my farm	194 (50)	94 (24)	15 (4)	38(1)	47 (12)	2.10	1.420
I am aware of government policies and incentives that support the adoption of IPM practices in agriculture	64 (17)	38 (10)	34 (8)	94 (24)	158 (41)	3.63	1.496
I feel confident in my ability to identify and monitor pest populations in my crops as part of IPM	95 (25)	18 (4)	8 (2)	54 (14)	213(55)	3.70	1.696
I perceive IPM as a cost-effective approach to pest management compared to conventional pesticide use	166 (43)	115 (31)	45 (11)	28 (7)	34 (8)	2.10	1.271
I feel that IPM practices are environmentally friendly and reduce the negative impact of pesticides on the ecosystem	279 (72)	71 (18)	23 (6)	7 (2)	8 (2)	1.44	0.850
I would recommend IPM practices to other farmers in my community	14 (38)	80 (21)	63 (16)	32 (8)	67 (17)	2.47	1.486
Overall Mean = 2.41							

NB: S.D = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, S.A = Strongly Agree)

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3.3. Adoption of IPM Practices

The mean scores provided for different categories of IPM practices, as presented in Table 3, suggest that, on average, farmers practice these methods at a relatively low level. Cultural practices within IPM received a mean score of 2.34, indicating limited implementation of methods like crop rotation or planting resistant varieties. Biological practices, with a mean score of 1.67, are also practised at a low level, suggesting a lesser inclination toward using natural predators or parasites for pest control. Similarly, mechanical/physical practices (mean=2.31) and chemical practices (mean=2.29) within IPM are perceived to be at low levels of implementation. These findings underscore the potential for enhancing farmers' adoption of diverse IPM strategies through targeted education and support, ultimately improving sustainable pest management practices while minimising negative environmental and health impacts. These results are supported by Ouedraogo *et al*. (2020), Kuwornu *et al*. (2018), and Akpalu *et al*. (2017), who reported that the level of adoption of IPM practices was generally low. The implications of the low mean scores for various Integrated Pest Management (IPM) practices among farmers are noteworthy. Firstly, it suggests that farmers may not fully understand or appreciate the advantages of these practices in sustainable pest management. Secondly, the limited adoption of IPM practices implies that conventional pesticide use may still be prevalent, which can have negative environmental and health consequences. There is a need to increase awareness and access to IPM practices among smallholder farmers in Ghana (Baffoe *et al*., 2015).

TABLE 3: Adoption of IPM Practices

IPM Practices	Never F (%)	Rarely F (%)	Sometimes F (%)	Often F (%)	Always F (%)	Mean	Std. Dev.
Cultural practices (Mean=2.34)							
Do you practice crop rotation?	74 (20)	95 (24)	92 (24)	61 (15)	66 (17)	2.88	1.352
Do you practice intercropping during your planting season?	114 (30)	55 (14)	69 (17)	73 (18)	76 (20)	2.85	1.508

Do you prune your tomato plant?	166 (43)	115 (31)	45 (11)	28 (7)	34 (8)	2.10	1.271
Do you practice staking as tomato plants grow?	279 (72)	71 (18)	23 (6)	7 (2)	8 (2%)	1.44	0.850
Do you plant resistant varieties?	135 (35)	86 (22)	81 (20)	31 (9)	55 (14%)	2.45	1.399
Biological (Mean=1.67)							
Do plant companion crops together with your tomatoes?	189 (49)	96 (25)	49 (12)	10 (3)	44 (11)	2.03	1.319
Do you use beneficial nematodes? Eg. Steinernema feltaie.	277 (71)	82 (21)	19 (5)	6 (2)	4 (1)	1.40	0.745
Do you use birds to combat pests in your tomato farm?	290 (74)	38 (9.7)	48 (12)	11 (3)	1 (0.3)	1.44	0.835
Do you use biological pesticides to combat pests? Eg. Neem oil	217 (56)	65 (17)	56 (14)	31 (8)	19 (5)	1.89	1.207
Do you introduce natural predators on your farm when it gets infested by pests? Eg. Predatory bugs	277 (71)	30 (8)	46 (12)	23 (6)	12 (3)	1.62	1.097

Mechanical/Physical practices (Mean=2.31)							
Do you handpick pests such as caterpillars and beetles?	189 (49)	96 (25)	49 (12)	10 (3)	44 (11)	2.03	1.319
Do you use physical barriers to prevent pests from accessing the tomato plants?	90 (23)	51 (13)	96 (25)	95 (25)	56 (14)	2.94	1.372
Do you use traps for capturing and monitoring insects?	103 (27)	44 (11)	87 (23)	100 (25)	54 (14)	2.89	1.408
Do you cultivate your tomato crops mechanically?	297 (77)	60 (15)	18 (5)	9 (2)	4 (1)	1.36	0.766
Chemical practices (Mean= 2.29)							
Do you spray your tomato crops with selective insecticides?	277 (71)	82 (21)	19 (5)	6 (2)	4 (1)	1.40	0.745
Do you spray your tomato crops with fungicides?	158 (41)	46 (12)	55 (14)	87 (22)	42 (11)	2.03	1.472
Do you spray your tomato crops with herbicides?	15 (4)	43 (11)	96 (25)	130 (33)	104 (27)	3.68	1.10
Do you spray your tomato crops with nematicides?	187 (48)	97 (25)	48 (12)	18 (5)	38 (10)	2.03	1.295

Note: F= Frequency

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3.4. Factors That Influence the Adoption of Integrated Pest Management by Tomato Farmers

Factors influencing tomato farmers about their adoption and utilisation of IPM practices were assessed to highlight empirical perspectives, considering the dynamics of the influencing factors concerning the four categories of IPM, which in this study are cultural, biological, mechanical/physical, and chemical. Table 4 highlights the results of the estimated regression model.

TABLE 4: Factors That Influence Farmers' Adoption of Integrated Pest Management (IPM)

Variables	Cultural	Biological	Mechanical/Physical	Chemical
	Coef. (Std. Error)	Coef. (Std. Error)	Coef. (Std. Error)	Coef. (Std. Error)
Sex	-0.116	-0.231	-0.562***	-0.214
	(0.157)	(0.194)	(0.163)	(0.150)
Marital Status	-0.0407	-0.0382	-0.0708	-0.0422
	(0.0687)	(0.0854)	(0.0693)	(0.0658)
Age	0.00570	-0.00147	-0.0504***	-0.0535***
	(0.0128)	(0.0160)	(0.0134)	(0.0124)
Years of formal education	0.000183	-0.0358	0.0585***	0.0234
	(0.0217)	(0.0288)	(0.0222)	(0.0208)
Land ownership type	-0.302***	-0.0331	-0.232**	-0.0209
	(0.102)	(0.138)	(0.109)	(0.0972)
Number of dependants	-0.112***	-0.0639	-0.0550	-0.0457
	(0.0430)	(0.0662)	(0.0434)	(0.0391)
Farm size (acres)	0.0383	-0.00317	-0.157***	-0.0677
	(0.0617)	(0.0695)	(0.0582)	(0.0572)
Number of workers	0.0562**	-0.0142	0.0959***	0.0755***
	(0.0231)	(0.0371)	(0.0236)	(0.0232)
Type of workers	-0.143	-0.567***	0.424***	0.0284
	(0.133)	(0.216)	(0.155)	(0.128)
	0.399***	0.0223	-0.636***	0.0642

Number of tomato farms	(0.120)	(0.124)	(0.119)	(0.107)
Farming experience	0.0269**	0.00591	0.0452***	0.0700***
	(0.0124)	(0.0161)	(0.0131)	(0.0126)
Farmer group	-1.128***	-1.221***	-0.964***	-0.619***
	(0.202)	(0.330)	(0.184)	(0.172)
Access to extension services	0.397**	0.613*	0.401*	0.586***
	(0.198)	(0.340)	(0.205)	(0.189)
Constant	-0.736	-0.127	2.006***	0.993*
	(0.623)	(0.822)	(0.654)	(0.587)
Log-likelihood	-667.183			
Wald (56)	311.95			
Prob > chi^2	0.000			
Observations	388			

Standard errors in parentheses NB: *** p<0.01, ** p<0.05, * p<0.1

As highlighted in Table 4, some influencing factors showed statistical significance across three components of IPM practices. These influencing factors were the number of workers, farming experience, farmer groups, and access to extension services. Technically and experientially, implementing all four components of IPM practices is not only time-demanding but also labour-intensive, which makes the availability of more labour and farmhands a great motivation to realise the sustainable and evidential impacts of IPM practices (Kihoro *et al.*, 2021; Kumar *et al.*, 2020). Tomato farmers with more access to farm labour showed significant and positive adoption possibilities of cultural, mechanical, and chemical IPM practices. This also reveals labour's relevance in realising sustainable food production. The influencing impacts of extension services and engagements cannot be undermined in promoting the adoption of sustainable agricultural practices, of which IPM practices are key. Access to extension services exposes farmers to both practical and theoretical orientations in dealing with pests and disease infestations. Education and the awareness farmers get through extension engagements empower them to adequately harness and appropriately apply IPM practices in response to their farm needs, influencing their decisions to adopt and utilise all four components of IPM (Uwagboe, 2016).

It was also revealed that experienced farmers, with their likelihood of having a deeper understanding of the benefits and techniques associated with these IPM components, are more inclined to adopt them as part of their pest management strategies. Experienced farmers can also manage and balance the application of conventional measures with IPM practices depending on their intuitiveness and the nature of their crop needs, hence their higher levels of adoption. However, it was seen that farmers' experience neither influenced statistically their adoption of biological-IPM practices positively nor negatively, which may probably be due to the complications and complexities of biological-IPM practices (Kumar *et al*., 2020; Uwagboe, 2016). It was very interesting to realise the negative influence of association with farmer groups on farmers' decision to adopt all four IPM components. Without hasty conclusions, it must be recognised that farmer groups are characterised and influenced by inherent organisational norms, leadership orders, and collective decision-making processes that influence the attitudes and behaviours of members towards certain production practices. The assumption is that association with farmer groups is supposed to enhance the adoption of production practices. Still, in many cases, farmers join farmer groups based on their respective ambitions, such as access to the market, inputs, labour assistance, and credit (Dara, 2019; Khoro *et al*., 2021). Situations like this are likely to intuitively shift their focus from IPM training and workshops.

As highlighted in Table 4, other specific factors significantly influencing adopting culturally-related IPM practices were land ownership, number of dependents, and number of tomato farms. Empirically, ownership of tomato farmland and the number of dependents negatively influenced farmers' adoption, as opposed to the number of tomato farms, which had a positive impact. In recent developments and studies in sustainable agricultural practices, the issue of land tenure systems and ownership of farmlands have been most often highlighted as an impediment to the motivation of adopting and practising sustainable and nature-based production practices. (Poudel & Dhakal, 2020; Dara, 2019; Thomas *et al*., 2010) From combating productive normative issues from climate change to pests and diseases, land ownership appears to be a limiting factor in farmers' drive to adopt sustainable practices (Kihoro *et al*., 2021). It is seen that farmers land tenure dynamics inform the long-term and short-term productive investments that farmers establish on their farmlands, which directly and indirectly translates into their production outcomes (Kumar *et al*., 2020).

The study recorded direct ownership of tomato farmland at 31% against hired and leased farmlands (69%), highlighting the negative impacts of land ownership on culturally related IPM practices in tomato production. Farmers are unwilling to work out the labour-intensive and time-demanding cultural IPM practices, which are also seen to have long-lasting impacts on the farmlands (Poudel & Dhakal, 2020). Concerning household dependants on farmers having a negative influence on adoption decisions, it is seen that farmers with larger households may be involved in other livelihood diversification activities to cater to the household needs that may not allow them to make time to apply cultural IPM practices appropriately, hence their reliance on pesticides as a time-saving solution (Saeidi 2012). The huge investments that go into managing multiple farms deter farmers from compromising the possibilities of their outputs to long-lasting impacts of pests and diseases, hence causing them to balance their pest management needs with culturally-related IPM strategies, which not only leave short-term impacts but impacts across production seasons (Gott and Coyle, 2019). Progress with sustainable pest management practices in vegetable production cannot be recounted without recognising the heights at which farming experiences have influenced the process (Dara, 2019).

Concerning biologically related IPM practices, the type of farm worker was seen to negatively influence farmers' adoption. The type of farm workers showing a negative influence on adoption signifies the domineering and relational roles that different forms of farm labour may have on adopting and utilising sustainable agricultural practices (Dhaka, 2020; Thomas *et al.*, 2010). The significant negative relationship also relays that certain farm workers may have different theoretical and experiential inclinations to biological IPM practices and have less knowledge and applicability of biological IPM practices. Farm labour preferences, familiarity with conventional pest management practices, or resistance to change may need to be examined. It is critical to understand farm workers' perspectives and attitudes when adopting biologically related IPM practices. (Dara, 2019). Also, farmers need to transfer implementation strategies for IPM practices to farm workers to reduce the negative impacts.

Concerning chemical IPM methods, an additional influencing factor that was seen to negatively and statistically influence farmers' adoption was the age of farmers. This brings to light the age descriptives of the farmers, with a minimum of 21 years to a maximum of 62 years and an average of 42 years. The result implies that the more farmers age, the more their drive and motivation to adopt chemical IPM methods are reduced. Chemical IPM methods appear too technical, with modified applicable knowledge according to the trends and modifications in the make-ups of pests and diseases. Aged farmers may not be privy to these modifications as they may be more accustomed to inherent traditional farm management practices that may be seen to be enough for them to combat pests and diseases. On the other end, aged farmers may want to defer the huddle of going through the complexities involved in implementing biological methods, hence, their shift to conventional practices (Saeidi, 2012; Dara, 2019)

Mechanical IPM methods were revealed to have more statistical and significant relations with the most influencing factors. Additional factors that had a negative and significant impact on farmers' adoption were sex, age, land ownership, and farm size. In contrast, years of formal education and the type of farm workers positively and significantly impacted farmers' adoption. The mechanical and physical nature of mechanical IPM methods deters tomato farmers who are aged, especially women, from implementing mechanical IPM methods. Due to the possibilities of mechanical IPM methods, it may be great to advocate for more hired labour for tomato farmers who are weak and aged, as a type of farm worker showed a positive influence in adoption. Hired workers (58%) may be more energic and physically built to undertake mechanical farm management practices (Dhaka, 2020; Thomas *et al*., 2010)). Education has shown its prowess in adopting and implementing sustainable production practices, of which IPM is key (Gott and Coyle, 2019). More years spent in formal education enhances farmers' intuitiveness and pest and disease management approaches on their farms. More experiential education and training are needed to influence farmers to adopt mechanical IPM methods in tomato production. Farm size and number of farms negatively influencing farmers' adoption of mechanical IPM methods reveals the time-demanding nature of mechanical IPM methods, which contradicts the time-sensitive nature of farmers with more farms and larger farm sizes, hence their shift to quick fixes and conventional practices of pest and diseases management (Saeidi, 2012).

3.5. Perceptions of Tomato Farmers on the Impacts of Integrated Pest Management Practices

Tomato farmers' perception of IMP practices was assessed to empirically ascertain the adoption possibilities of IPM practices in realising sustainable tomato production. From Table

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5, an overall average perception index of 1.93 showed that most tomato farmers disagreed with the positive perception statements about IPM practices.

TABLE 5: Farmer's Perception of the Effects of Integrated Pest Management (IPM)

Effects	S. D F (%)	D F (%)	N F (%)	A F (%)	S. A F (%)	Mean	Std. Dev.
IPM helped to reduce the number of pesticides I use in tomato farming	217 (56)	82 (21)	18 (5)	15 (4)	56 (14)	2.00	1.437
IPM helped increase my tomato yield	202 (52)	100(27)	17 (4)	17 (4)	52 (13)	2.01	1.397
IPM helped to reduce the cost of tomato production	240 (62)	109(28)	17 (4)	12(3)	10 (3)	1.56	0.911
IPM helped to reduce the risk of pest and disease infestation	202 (52)	84 (22)	20 (5)	41 (11)	41 (11)	2.06	1.395
IPM has improved soil health	193 (50)	78 (20)	50 (13)	46 (12)	21 (5)	2.03	1.343
Overall Mean = 1.932							

NB: S.D = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, S.A = Strongly Agree, F= frequency

The potential tomato farmer who is an adopter of IPM has an increased knowledge and technical burden due to the complexity of specific IPM approaches. For instance, as by Peterson *et al*. (2018), most biopesticide applications need to be timed precisely for maximum effect; certain pheromones only attract male insects and only work to lower pest populations when administered across a large region; and grafting necessitates required humidity management for the grafted seedlings. Adoption success depends not just on the IPM technique but also on how it is implemented. Reflecting on Orr (2003), IPM proponents, according to Peterson *et al*. (2018), have missed the mark by obsessing over methods or strategies rather than providing farmers with the necessary tools or training to apply them. Farmers' focus on IPM practices and not means of utilisation is seen to render them not to realise the full potential of IPM practices (Jørs *et al*., 2017), influencing their negative perceptions of the impacts of IPM practices in their production activities. This suggests that IPM training and workshops should focus on orienting tomato farmers more on the means of IPM implementation and not just transfer the knowledge of awareness of the practices (Kumar *et al*.,2018). Means of implementing IPM practices have become essential in production practices especially due to the diverse and evolving conventional changes in production activities; hence, a modification in the extension and learning approaches through which farmers are engaged in IPM adoption and implementation (Bello-Bravo *et al*., 2017).

3.6. Challenges of IPM Adoption Faced by Tomato Farmers

The unanimous agreement among all tomato farmers revealed that the significant challenges in IPM adoption are "resistance to change," "risk perception," and the "high cost of IPM"." In contrast, the least perceived challenge was “social and cultural barriers to adoption”, as highlighted in Table 6.

TABLE 6: Challenges Faced by Farmers in the Adoption of Integrated Pest Management

Challenges	Mean Rank	Ranking
Resistance to change	6.97	1st
Risk perception	6.96	2nd
High cost of IPM	6.95	3rd
Unavailability of technical support and extension services	6.93	4th
Unfavourable government policies and regulations	6.91	5th
Limited access to quality inputs	6.34	6th
Poor market access and price instability	6.21	7th
Social and cultural barriers to adoption	4.32	8th
N = 388; Kendall’s Wa: 0.423; Chi-Square: 1148.870; df: 7; Asymp Sig: 0.000		

Regarding resistance to change, it suggests that many farmers may be entrenched in traditional pest control methods and hesitant to embrace new approaches like IPM. This resistance can stem from factors such as familiarity with existing practices, concerns about the effectiveness of IPM, or reluctance to invest time and effort in learning and implementing new techniques. Risk perception indicated that farmers may perceive IPM practices as riskier than conventional pest control methods. This perception could be due to concerns about potential

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crop losses during the transition to IPM, uncertainties about the outcomes of IPM practices, or a lack of confidence in their ability to manage pests effectively using IPM practices. Regarding the high cost of IPM, the implication is that IPM often requires initial investments in training, equipment, biological control agents, and monitoring tools. Farmers may find these costs prohibitive, especially if they have limited access to financial resources or perceive the returns on investment as uncertain (Kumar *et al*., 2018)

Risk and uncertainty can influence decisions about IPM adoption, but the degree of that influence varies depending on the practice of the issue and the type of risk. IPM is a type of informal risk management since it addresses pest management instead of pest control (Peterson *et al*., 2018). Additionally, by reducing pest populations, the likelihood of infestation decreases. Market risks such as shifting input and product prices may aid adoption when IPM techniques replace purchased inputs like pesticides. Exposure to risks associated with the market is reduced when non-bought IPM inputs are used instead of purchased ones. Using less-toxic inputs, for example, also reduces additional threats to animal and human health. Adoption, however, indicates increased exposure to market risk when IPM entails the acquisition of more costly alternatives. IPM techniques that require a lot of manual labour might also shield adopters from market risks. IPM can increase or decrease exposure to market risks, and the impact of risks on adoption depends on various factors (Parsa *et al*., 2014; Jørs *et al*., 2017).

Possibly more harmful than risk is uncertainty. Lack of knowledge of everything required to assess risk is called uncertainty. Whether or not specific techniques will be effective is a major consideration when adopting IPM, and it is a significant concern. According to Peterson *et al*. (2018), this uncertainty will cause adoption to decline. It also increases over time as diseases and pests change. Yet, integrated pest management (IPM) techniques might be alluring when disease and pest outbreaks are unpredictable. In contrast to an IPM system based on scouting that waits until the pest or its harm is present in the field, a conventional approach would involve a preventative spray to stop an uncertain breakout (Alwang *et al*., 2001; Kumar *et al*., 2018).

4. CONCLUSION

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Generally, farmers do not agree with the perception statement, implying a low level of awareness and knowledge of IPM. Adoption of the four categories of IPM practices is low. Factors such as the type of land ownership, number of dependents, number of workers, number of tomato farms, farming experience, farmer group membership, and awareness of integrated pest management play a significant role in influencing the adoption of cultural practices under IPM. The presence of more workers and access to extension positively influenced the adoption of cultural practices. At the same time, factors like land ownership type and membership of farmer groups had a negative influence. Gender, religion, age, years of formal education, land ownership type, farm size, number of workers, type of workers, number of tomato farms, farming experience, farmer group membership, and the awareness of integrated pest management influence the adoption of mechanical practices. The presence of more workers, skilled labour, higher formal education, and access to extension positively impact the adoption of the mechanical practice, while having a larger farm size and more tomato farms have a negative influence. Age, number of workers, farming experience, farmer group membership, and awareness of integrated pest management are key factors affecting chemical practices under IPM. Farmers perceive a low level of effect of IPM on their farming activities. The three main challenges affecting farmers' adoption of IPM are resistance to change, risk perception, and the high cost of IPM.

Based on the conclusions, the following recommendations can be made: the Ministry of Food and Agriculture must strengthen and expand agricultural extension services to provide ongoing support, guidance, and technical assistance to farmers in implementing IPM practices. If certain resources such as organic fertilisers, quality seeds, and biocontrol agents such as beneficial insects, a natural enemy of pests, are provided to the farmers, it would make implementing integrated pest management easier and reduce reliance on chemical methods of controlling pests. Financial incentives, subsidies, or grants could help farmers offset the initial costs of adopting IPM practices. This can make IPM more financially accessible and attractive to a broader range of farmers. Establishing IPM demonstration farms where farmers can witness the benefits of IPM practices firsthand can serve as learning hubs and inspire other farmers to adopt similar techniques. In addition, farmer groups should also set their priorities to holistically include sustainable production practices as key values for the collective good and inform members of the consequences of doing otherwise. On the other hand, farmer

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groups should intensify both theoretical and experimental engagements of IPM practices to enhance the implementing experience of members.

5. DATA AVAILABILITY STATEMENT

Data will be made available upon request.

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