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Driving Integrated Pest Management (IPM) Adoption in Date Palm Farming: Key Factors, Challenges and Economic Opportunities

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ABSTRACT

This study investigated factors affecting Integrated Pest Management (IPM) adoption among date palm farmers in Al-Ahsa Governorate in Saudi Arabia, identifying challenges and opportunities towards sustainable agriculture. Approximately half of the farmers surveyed were adopting the IPM techniques. The key drivers for adopting the IPM comprised the tree inspection frequency, farm size, income, and education. However, experience alone does not guarantee openness to innovation, underscoring the need for tailored interventions. The research advocates for training workshops, financial incentives, and resource accessibility to enhance IPM adoption and foster sustainable practices. Moreover, fostering awareness of advanced monitoring technologies and addressing shortcomings in agricultural extension services could further enhance IPM uptake. These measures are essential for promoting sustainable agricultural practices, reducing pest losses, and improving the long-term productivity and profitability of date palm farming in the region.

Keywords: Integrated Pest Management, Date Palm, Logistic Regression, Sustainable Agriculture, Saudi Arabia

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INTRODUCTION

Date palm cultivation is integral to Saudi Arabia's agricultural landscape, with Al-Ahsa Governorate being a key region globally recognized for its significance. The Al-Ahsa Oasis is the largest interconnected date palm oasis, spans 375,000km^2, and contains over 2.5 million date palm trees, as shown in Fig. 1. It accounts for 69% of the Eastern Province and includes approximately 30,000 agricultural holdings, with 20,000 hectares dedicated to palm farming (Saudi Press Agency, 2020; Kassem et al., 2020).

Despite its agricultural potential, Al-Ahsa faces challenges, primarily the red palm weevil, first detected in 1992 (Massoud et al., 2011). This invasive pest poses severe risks to date palms, necessitating sustainable pest control strategies. Integrated Pest Management (IPM) has emerged as a crucial solution, incorporating diverse methods such as monitoring, pheromone traps, insecticides, infected tree removal, and quarantine measures. Effective IPM practices also emphasize farmer training and awareness campaigns to enhance their adoption (El Bouhssini & Faleiro, 2018; Kassem et al., 2020). The Ministry of Environment, Water, and Agriculture's Agriculture Directorate has implemented IPM strategies in Al-Ahsa for over 25 years. These efforts have met with varying success, highlighting the need for ongoing innovation and collaboration among government bodies, researchers, and farmers to address evolving pest management challenges (Abraham et al., 2000). Given the economic significance of the date palm industry, enhancing IPM implementation is critical for maintaining agricultural sustainability.

This research examines the influencing factors of adapting the IPM and identifying the patterns and barriers. The findings are expected to facilitate knowledge dissemination among farmers, reducing dependency on external support and bolstering IPM practices' credibility (Norton et al., 2005). Understanding farmer adoption behavior allows for IPM programs to be aligned with their specific needs. However, global IPM adoption studies indicate common challenges, including insufficient awareness, inadequate resources and regulatory gaps (Faleiro et al., 2019).

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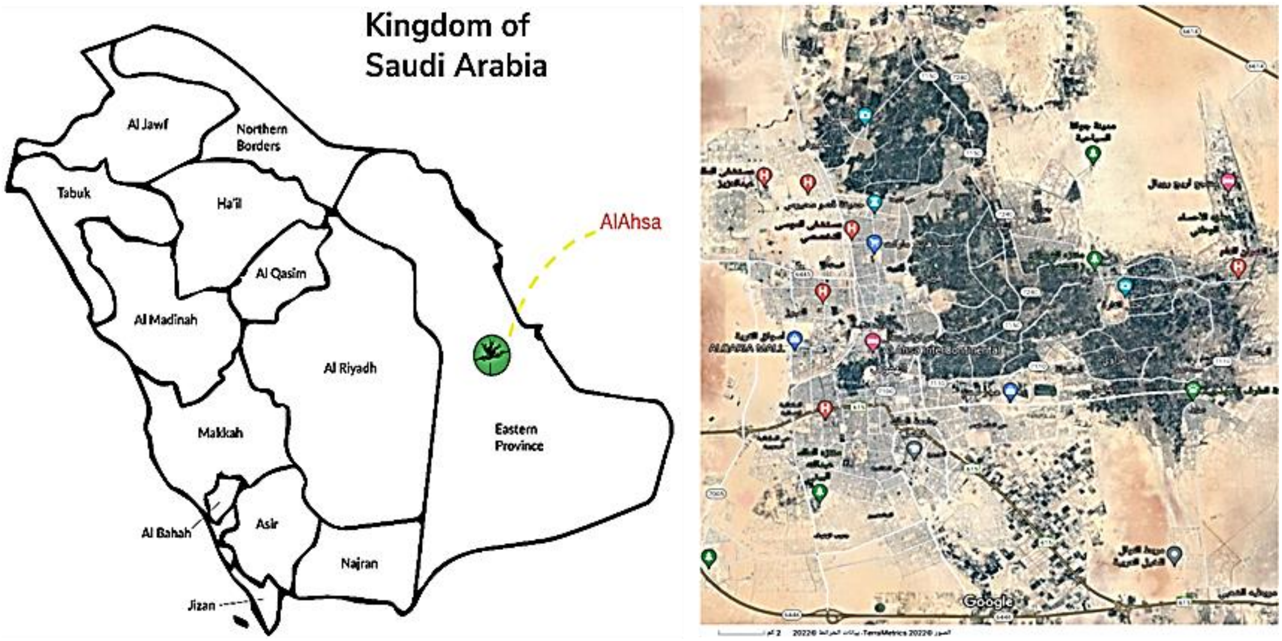

Fig. 1: Map of Saudi Arabia highlighting the study area and regional distribution within Al-Ahsa Governorate (Google Maps 2024).

Food loss, including that of dates in Saudi Arabia, impacts food security, with 18% lost in production and 24% post-harvest. Modern technologies and IPM can reduce waste and improve storage (Alhamdan et al., 2024). Studies in different regions highlight these trends. For instance, Shrestha et al. (2024) report that IPM adoption correlates with farm size and expert advice availability. In Serbia, social pressures and farming control were found to influence IPM use, though education played a lesser role (Despotović et al., 2019). Similarly, (Angon et al. 2023) suggested that IPM adoption benefits ecological balance and pesticide reduction but requires government support and access to modern tools like IoT and drones. Research in Indonesia and Poland has also underscored IPM's potential but identified persistent gaps in pesticide management and challenges in large-scale farms (Piwowar, 2021; Sari et al., 2024). In Saudi Arabia, (Alotaibi et al. 2022) found moderate IPM adoption regarding the red palm weevil control efforts, mainly influenced by age, education, and farm size. They emphasized the use of digital tools for pest detection. Despite advancements, resource constraints remain a barrier to comprehensive pest management (Faleiro et al., 2019). Collaborative initiatives and enhanced educational outreach are essential for bolstering IPM adoption and ensuring sustainable and economically viable strategies (Creissen et al., 2021).

Recent data in Fig. 2 indicate progress in combating the red palm weevil in Saudi Arabia, with infestation rates peaking in 2019 and declining significantly by 2022. Al-Ahsa accounted for 65% of the cases, with substantial treatment and tree removal efforts exceeding 70% of the total removals in the Eastern Province. Other regions, like Qatif, recorded lower rates, while Al-Qaryat Al Ulya and Hafar Al-Batin exhibited minimal infection levels. Significant gaps in Saudi Arabia's red palm weevil (RPW) management strategies make pest control unsustainable and eradication difficult (Abdel-Banat et al., 2023). Farmers also face obstacles such as insufficient knowledge, limited resources, and low awareness of the IPM's benefits, further hindered by inadequate support mechanisms like training programs and financial incentives. Unfortunately, there are limited data about the IPM adoption among date farmers in Al-Ahsa Governorate, which highlights the need for a deeper analysis to address key challenges and opportunities. We contribute to the existing literature by filling this gap, as our study aims to evaluate the economic impacts of IPM, explore challenges to adoption, and identify factors influencing farmer participation. By addressing these issues, the study seeks to improve pest control strategies, enhance agricultural productivity, and support the sustainable development of date palm farming in Al-Ahsa and beyond.

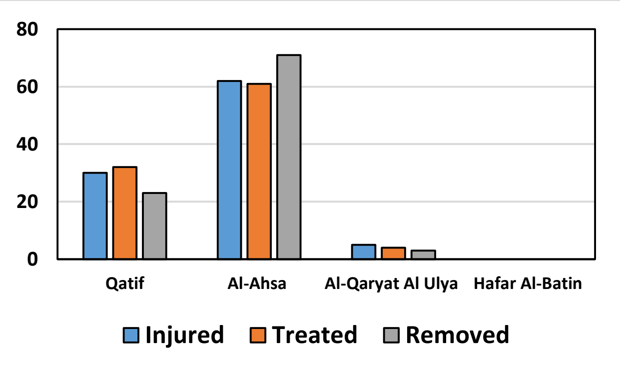

Fig. 2: Average percentages of palm trees infected, removed, and treated in the Eastern Province (2018-2022) (MEWA, 2022).

MATERIALS & METHODS

The IPM adoption is a latent variable, x^*, observed as follows:

$$x = \begin{cases} 1 \; if \; x^* > 0 \\ 0 \; if \; x^* \leq 0' \end{cases}$$

taking the value of 1 when a farmer adopts IPM and 0 otherwise.

Logistic regression remains a pivotal statistical technique for modeling a binary or categorical outcome, often employed in studies exploring relationships between several predictor variables and dichotomous or ordinal outcomes (Hosmer et al., 2013). Its applications in agricultural practices, including the adoption of sustainable farming methods, have seen extensive use due to its ability to handle diverse predictor variables, including socioeconomic and environmental factors (Hashim et al., 2023). Unlike linear regression, which predicts a continuous outcome, logistic regression is best for cases where the outcome is categorical, such as whether a condition is present or not or if a practice is adopted (Menard, 2002).

The logistic regression method involves identifying relevant independent variables, or factors, that could affect the probability of the outcome. These factors may be quantitative (like age or income) or qualitative (like gender or location) and must have a potential influence on the outcome's likelihood (Menard, 2002). The logistic model is fitted to the data by maximizing a likelihood function, which adjusts the predictor variable coefficients to match the observed results best. These coefficients indicate how each unit increases in a predictor changes the log odds of the outcome, helping researchers measure each factor's effect (Hosmer et al., 2013).

To identify the key social, personal, and economic factors influencing farmers' adoption of IPM as a binary descriptive variable (whether a farmer adopts IPM or not), the logistic regression model is proposed as a suitable tool for examining this relationship. The logistic regression model is defined as a statistical method for investigating the relationship between a nominal-level dependent variable and one or more independent variables, often referred to as explanatory variables. These explanatory variables can be of any measurement level (Al-Zahrani et al., 2021).

This approach is particularly valuable because it allows researchers to understand not only whether farmers adopt IPM practices but also the extent to which various factors contribute to that decision. By employing the logistic model, this study aims to provide insights into how demographic characteristics, economic conditions and personal motivations interact to influence the adoption of sustainable agricultural practices. This understanding can help policymakers design more effective outreach and support programs that encourage the adoption of IPM, ultimately contributing to improved agricultural productivity and sustainability in the region.

To analyze the factors influencing the adoption of IPM, this study will utilize the logistic regression model, expressed by the following equation (Freedman, 2009):

$$\mathrm{Log_{it}}(\theta(\mathrm{x})) = \mathrm{Log_e}\left(\frac{\theta(\mathrm{x})}{1-\theta(\mathrm{x})}\right) = X'\beta \quad (1)$$

where $\theta(\mathrm{x})$ represents the probability of a farmer adopting IPM, given the social, personal, and economic factors affecting the farmer. It can be expressed as follows:

$$\theta(\mathrm{x}) = \Pr(\mathrm{Y}=1|\mathrm{X}) = \frac{\mathrm{e}^{X'\beta}}{1+\mathrm{e}^{X'\beta}} \quad (2)$$

$[1-\theta(\mathrm{x})]$ indicates the probability of a farmer not adopting IPM, which can be represented as follows:

$$1-\theta(\mathrm{x}) = \Pr(\mathrm{Y}=0|\mathrm{X}) = \frac{1}{1+\mathrm{e}^{X'\beta}} \quad (3)$$

The ratio $\left(\frac{\theta(\mathrm{x})}{1-\theta(\mathrm{x})}\right)$ is known as the odds ratio (Hosmer, 2000). $\mathrm{Logit}(\theta(\mathrm{x}))$ serves as the link function that connects the independent variables with the dependent probability. $\log_e$ refers to the natural logarithm of the odds ratio.

Furthermore, the logistic regression model can be expanded to include multiple explanatory variables:

$$\log_{it}\left(\frac{\theta(\mathrm{x})}{1-\theta(\mathrm{x})}\right) = \beta_0 + \sum_{i=1}^{k}\beta_i X_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \quad (4)$$

This equation illustrates that the log-odds of adoption (i.e., the likelihood that a farmer will adopt IPM) is modeled as a linear combination of the independent variables $X1$, $X2$,...,.

This method provides valuable insights into how different influences interact and can help identify which factors are most significant in promoting the adoption of sustainable agricultural practices. Understanding these dynamics is essential for developing targeted interventions and policies that can facilitate the wider adoption of IPM, ultimately leading to improved agricultural productivity and sustainability in the region.

Data collection involved administering a structured questionnaire to 100 farmers in Al-Ahsa Oasis, aimed at gaining detailed insights into their agricultural practices, challenges, and technology adoption. The questionnaire was distributed in both traditional paper format and digitally through Google Forms, ensuring wide accessibility and a varied respondent pool.

RESULTS & DISCUSSION

Table 1 provides a descriptive analysis of the categorical variables. The number of adopters of IPM for red palm weevil reached 49 farmers out of a total of 100, representing a rate of 49%. It is noteworthy that this adoption rate was initially underestimated; some respondents claimed they were not to adopting IPM practices. However, after a detailed explanation of what IPM entails, it became evident that they were indeed implementing certain practices without being fully aware of their classification or terminology. Consequently, their adoption status was adjusted according to the definition of IPM. In contrast, the number of non-adopters of IPM among the farmers was 51, which accounts for 51%. The majority of adopters aged between 47 and 60 years old. In contrast, farmers younger than 47 or older than 60 years old were less inclined to adopt IPM. Also, adopters consisted of more literate farmers compared to non-adopters. Farming experience also mattered, with 42.9% of the adopters having over 35 years of experience, whereas 47.1% of the non-adopters fell in the mid-experience category of 18–35 years. This indicates that while the experience in farming is substantial among both groups, it does not necessarily correlate with IPM adoption, suggesting that other factors may also be at play (Sekabira et al., 2022).

Regarding employment, most adopters (55.1%) and non-adopters (54.9%) were unemployed. However, government employees were more likely to be adopters (32.7%) than private sector workers (6.1%). Concerning farm ownership, 71.4% of the adopters owning their farms, slightly higher than the proportion of farmers owning farms among non-adopters (66.7%). The irrigation methods showed a stark difference that drip irrigation was widely used by adopters (53.1%), whereas non-adopters relied predominantly on surface irrigation (72.5%). This highlights the role of modern irrigation techniques in

Table 1: The descriptive analysis of the categorical variables

Statement		Frequency		Percentage	
		Adopters	Non-Adopters	Adopters	Non-Adopters
Sample Members		49	51	49	51
Age	Less than 47 years	7	11	14.3	21.6
	years 60-47	25	22	51	43.1
	Over 60 years	17	18	34.7	35.3
Education	No education	3	11	6.1	21.6
	Reads and Writes	6	8	12.2	15.7
	Primary	10	7	20.4	13.7
	Intermediate	9	7	18.4	13.7
	Secondary	9	6	18.4	11.8
	University and above	12	12	24.5	23.5
Experience	Less than 18 years	13	11	26.5	21.6
	18-35 years	15	24	30.6	47.1
	Over 35 years	21	16	42.9	31.4
Non-Agricultural Work Type	Government Employee	16	13	32.7	25.5
	Private Sector	3	6	6.1	11.8
	Freelance	3	4	6.1	7.8
	Unemployed	27	28	55.1	54.9
Farm Ownership	Owned	35	34	71.4	66.7
	Rented	9	11	18.4	21.6
	Endowment	5	6	10.2	11.8
Inherited Work in Palm and Dates	No	5	8	10.2	15.7
	Yes	44	43	89.8	84.3
Irrigation Method Used	Surface Irrigation	23	37	46.9	72.5
	Drip Irrigation	26	14	53.1	27.5
Irrigation Water Source	Wells	30	30	61.2	58.8
	Public Irrigation Authority	18	20	36.7	39.2

Source: Data from the sample of farms in Al-Ahsa Governorate, 2019.

sustainable farming practices. Water sources, such as wells and public irrigation, are similarly utilized across both groups, suggesting limited differentiation in water access. A substantial 89.8% of the adopters came from families with a history in palm cultivation, compared to 84.3% of the non-adopters. This indicates that cultural continuity slightly supports sustainable practices like IPM (Bhatti & Sundram 2024).

Recent studies corroborate these findings, emphasizing the impact of knowledge dissemination, infrastructure improvements, and tailored policies. For example, Shrestha et al. (2024) found that structured advice and peer influence significantly drive IPM adoption globally, aligning with the Al-Ahsa findings, where middle-aged farmers (47–60 years) exhibited higher adoption rates. Similarly, a study in Bangladesh by Rahman (2022) highlighted how mass media and family involvement in training can improve IPM adoption. This approach could be particularly beneficial in Al-Ahsa, where family traditions already support sustainable practices. The disparity in irrigation practice use between the adopters and non-adopters echoes the findings of Angon et al. (2023), who stressed the importance of integrating modern technologies like IoT and drones in pest management. Drip irrigation's prevalence among the adopters in Al-Ahsa suggests its role as a gateway for broader technological adoption. Similarly, Alotaibi et al. (2022) observed that, in Saudi Arabia, awareness campaigns and digital tools improve pest detection, which could help convert the 51% of non-adopters in Al-Ahsa to adopters. The region's cultural history of palm farming, with 89.8% of the adopters inheriting the practice, indicates a strong foundation for incorporating modern pest management strategies into traditional systems.

This discrepancy highlights potential areas for education and resource allocation to encourage more sustainable practices among non-adopting farmers (Hessane et al., 2024). Overall, these results suggest that while there is significant adoption of IPM practices, various factors such as education, land ownership, and irrigation methods play crucial roles in influencing farmers' decisions. Further research could explore targeted strategies to enhance IPM adoption rates, ensuring the sustainability and productivity of date palm cultivation in the region (Abdel-Banat & El-Shafie, 2021).

Table 2 displays the descriptive analysis for the continuous variables. The adopters generally managed larger farms with an average size of 7.47 dunums compared to 6.74 dunums for the non-adopters. This trend suggests that larger farms may have the resources and incentives to implement IPM practices. Supporting recent studies, Shrestha et al. (2024) reported that larger farm sizes often correlate with higher adoption rates of advanced agricultural technologies due to the scale advantage in resource allocation. The results also indicate that the adopters' farms are located further from the governorate center, averaging 10.03 km compared to 8.96 km for the non-adopters. In terms of economic indicators, the adopters achieved higher average annual farm incomes per dunum, at SAR 3,703.25 (USD 987.5), compared to the non-adopters, at SAR 2,724 (USD 726.4). This economic advantage aligns with the findings of Angon et al. (2023), which highlighted that IPM adoption leads to reduced pesticide costs and improved yield quality. The higher number of palms per dunum for the adopters (31) compared to that for the non-adopters (28) further reinforces the potential efficiency gains linked to IPM strategies.

Finally, the most common price of dates in the selling season shows no significant difference between the adopters, at SAR 2.88/kg (USD 0.768), and the non-adopters, at SAR 2.89/kg (USD 0.771). This highlights that market dynamics, rather than IPM practices, dictate pricing.

Table 2: The descriptive analysis of the continuous variables

Statement		Minimum	Maximum	Average	Standard Deviation
Farm Area (dunum)	Adopter	0.50	50	7.47	8.18
	Non-Adopter	0.20	30	6.74	6.66
Distance from the Governorate Center (km)	Adopter	0.600	30.00	10.03	6.98
	Non-Adopter	1	20	8.96	5.14
Average Annual Farm Income	Adopter	242.08	11,127	3,703.25	2,484.10
(SAR/du) ***	Non-Adopter	117.2	7,495	2,724	1,563.1
Number of Palms (Palm/du)	Adopter	6	80	31	16.68
	Non-Adopter	2	86	28	15.56
Number of Palms Infested by Red Palm Weevil (Palm/du)	Adopter	0	10	1**	2.16
	Non-Adopter	0	20	1**	3.49
Most Common Price in Date Selling Season (SAR/kg)	Adopter	0.83	5	2.88	1.003
	Non-Adopter	1.25	6.25	2.89	0.74

Source: Data from the sample of farms in Al-Ahsa Governorate 2019, **Figures were rounded to the nearest whole number;*** 1 dunum (du)=1,000 m^2; 1 USD=3.75 SAR.

For instance, the market failure that results from information asymmetry could lead adopters to sell their dates at a price lower than the true value. However, the adopters' higher incomes suggest better production efficiency rather than price advantages. Combined with contemporary insights, these results underscore the economic and environmental benefits of IPM and emphasize the need for expanding education and resource access to encourage adoption (Denashurya et al., 2023).

Table 3 presents the results of the Hosmer–Lemeshow test for the goodness of fit of the data, indicating that the chi-square value is 5.231 with 8 degrees of freedom and a significance level of 0.733, which is greater than 5%. According to Sidibe (2005), if the significance level is less than 5%, it indicates a poor fit of the data to the binary model. In other words, the logistic model is adequate for fitting the given data and is suitable for estimating data at an acceptable level. Examining the influencing factors of IPM adoption is essential for designing policies improving the adoption rates among farmers in Al-Ahsa, as it provides insights into the barriers to and facilitators of effective pest management. By focusing on education and extension services, agricultural policies can be tailored to enhance the understanding and implementation of IPM practices, ultimately leading to better productivity and sustainability in date palm farming. Furthermore, engaging farmers to address their specific needs and experiences can significantly improve adoption rates and contribute to the overall health of the agricultural ecosystem in the region (Cabral et al., 2024). The influencing factors are divided into three categories. First, farm-related factors of farm era, quantity of dates production (Kg), total palms number, number of infested palms, and annual farm income. Second, factors related to farmer attributes of education and experience, in which we include a dummy variable that equals 1 if a farmer was literate and 0 otherwise. The last categories pertained to the red Palm Weevil, controlling for extension visits and monthly palm inspections.

Table 3: Results of the Hosmer–Lemeshow Chi-Square test for goodness of fit.

Hosmer and Lemeshow Test			
Sig.	df	Chi-square	Step
733	8	5.231	1

Table 4 presents the results of the logistic regression by estimating the model in equation (2), which identifies key factors influencing the adoption of IPM by farmers in Al-Ahsa Governate. Significant variables at the 5% level include the number of years of experience, number of palms on the farm, annual farm income, and monthly palm inspections, which had the strongest effect with an Exp(B) of 816.680, highlighting the critical role of regular inspections in IPM adoption. The number of years of farming experience negatively influenced the adoption probability, suggesting that more experienced farmers may rely on traditional methods. Similarly, larger farms with more palms are less likely to adopt the IPM. This aligns with the findings of Shrestha et al. (2024), finding that farm size and traditional practices affect IPM implementation, especially in resource-limited settings. Education positively impacted the likelihood adoption at the 10% significance level, with Exp(B5)=8.404, underscoring its role as a vital enabler. The studies by Despotović et al. (2019) and Sadique Rahman (2022) also emphasize the critical influence of education and extension services in adopting modern agricultural techniques. The annual farm income positively increases the probability of adoption, as higher income levels provide farmers with resources to invest in IPM technologies. This finding is supported by Angon et al. (2023), who noted that financial stability enables the adoption of advanced agricultural tools. Interestingly, agricultural extension visits were not significant, suggesting gaps in outreach or effectiveness. This is in line with the Ministry's reports that highlight shortcomings in extension services in developing regions. Monthly inspections emerged as the most decisive factor, suggesting that fostering awareness about pest monitoring and regular inspections could significantly enhance the IPM adoption probability. Recent advancements like IoT-based monitoring tools may further enhance these practices (Angon et al. 2023). This study shows that adopting IPM provides clear economic benefits for date palm farmers in Al-Ahsa. The farmers who used IPM experienced fewer pest losses, improved productivity, and higher returns. These findings align with those of Kassem et al. (2020), who highlighted that greater IPM adoption reduces economic losses from pests and offers long-term financial advantages. Both studies emphasized how IPM lowers costs, such as those of pesticides, and protects crops effectively. Therefore, this indicates that better-informed and resource-rich farmers are more likely to reap the economic advantages of IPM. Overall, the findings emphasize the need for tailored interventions focusing on education, income support, and inspection practices to promote sustainable IPM adoption. Combining these with advanced technologies and efficient extension services could yield long-term benefits for pest management in the region.

Table 4: Results of estimating the coefficients of the logistic regression model for factors influencing farmers' decision to adopt IPM in Al-Ahsa Province

Variable	B	S.E.	Wald	df	Sig.	Exp (B)
Production of dates	0.0003	0.0001	3.560	1	0.059**	1.000
Number of infected palms	-0.030	0.029	1.063	1	0.303	0.970
Years of experience	-0.080	0.038	4.386	1	0.036*	0.923
Number of palms in the farm	-0.022	0.008	7.567	1	0.006*	0.978
Education	2.129	1.201	3.143	1	0.076**	8.404
Annual farm income	0.000008	0.00003	4.547	1	0.033*	1.000
Agricultural extension visits	-0.763	1.052	0.526	1	0.468	0.466
Monthly palm inspections	6.705	1.449	21.424	1	0.000*	816.680
Farm area	0.0004	0.097	0.00002	1	0.996	1.000
Constant	-3.172	1.828	3.012	1	0.083	0.042
Chi-square			0.00			88.57

* Significant at the 5% level; ** Significant at the 10% level.

Conclusion and Recommendations: This research highlights the main factors influencing the IPM adoption among date palm farmers in Al-Ahsa Governorate. It shows both the challenges and opportunities of using this sustainable farming method. The study found that almost half of the farmers have already adopted IPM, which shows there is a good chance for more farmers to adopt it. As Wang et al. (2018) found, nearly half of the farmers have already adopted IPM, showing there is good potential for more farmers to use it. By offering targeted education and support, these practices can be spread more widely across the region. Several factors influence IPM adoption, such as how often farmers inspect their trees, the size of their farms, their income, and their level of education. These findings suggest targeted training and educational campaign to successfully promote the IPMand increase it adoption rates. Farmers with higher levels of education tend to use IPM more, which shows that raising awareness and providing training tailored to farmers' needs can help increase adoption. Ongoing education and support are key to encouraging sustainable farming. While farming experience is important, it does not always mean farmers are ready to adopt new practices like IPM. Older or more experienced farmers may be less likely to try new methods, even though they have the knowledge. To help this group, this study suggests that training should emphasize the practical benefits of IPM, particularly for experienced farmers. Creissen et al. (2019) found that all of the farmers surveyed used some IPM practices, but only 5.8% fully adopted them. This shows the importance of using measures to help increase IPM use. Finally, this research also recommends the creation of training sessions and workshops to fill the knowledge gaps among farmers. These should focus on how IPM can help reduce costs, increase crop yields, and improve sustainability. Demonstration of real-life examples of successful IPM use would potentially motivate farmers to try these methods. Encouraging farmers to inspect their trees regularly is another key recommendation. Demonstration projects showing the benefits of early pest detection can help build farmers' confidence in these practices. Through targeted support and education, more farmers can adopt IPM, leading to better farming practices and a stronger agricultural sector.

Conflicts of Interest: The authors declare no conflicts of interest.

Author's Contribution: Abdullah Aldakhil and Yosef Alamri performed research design, execution, data analysis, interpretation, and manuscript writing. Mahdi Alsultan and Abdulaziz Alduwais followed up and contributed to writing evaluated the experiments throughout the research period. Fuad Alagsam, and Kamaleldin Bashir made valuable contributions to the discussion, revision, editing, and proofreading of the final manuscript.

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