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PLANT PROTECTION APPROACHES IMPACT ON ACHIEVING AGRICULTURAL SUSTAINABILITY IN IRAQ: AN APPLIED STUDY

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SUMMARY

The study evaluated the effectiveness, economic viability, and environmental implications of various strategies, including chemical pesticides, biological control agents, integrated pest management, and cultural and mechanical practices, to investigate the impact of different plant protection approaches on the sustainability of the Iraqi agriculture sector, Field experiments transpired across various regions of Iraq, with the data recorded through survey interviews of the farming community. The findings provide insights into the efficacy of plant protection measures in improving crop yields, reducing economic losses, and minimizing environmental risks. The study highlights the importance of promoting sustainable plant protection practices to ensure long-term viability and the Iraqi agriculture sector's resilience. The presented results will have practical implications for policymakers, agronomists, and farmers, enabling evidence-based decision-making and targeted interventions. Additionally, the assessment also explored potential areas for further research. It also acknowledged the constraints and boundaries of the study.

Keywords: Agricultural sustainability, plant protection methods, chemical pesticides, biological control, integrated pest management, cultural practices

Key findings: The correlation coefficient was significantly positive, proving the null hypothesis was baseless. It also verified the validity of the main hypothesis 1 of the research through the analysis of the hypothesis 2. According to the scale, in hypothesis 3, the correlation was also significantly positive.

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INTRODUCTION

Agricultural sustainability has become a critical concern worldwide, as the planet's growing population continues to put pressure on food production systems. In Iraq, a country with a long history of agricultural practices, achieving sustainable agricultural development is imperative (Nath and Saikia, 2022). Therefore, the successful implementation of plant protection measures could play a pivotal role in ensuring the agricultural practices' sustainability (Gill and Goyal, 2016). Plant protection methods encompass a wide range of strategies and techniques aimed at managing pests, diseases, and weeds in agricultural systems while minimizing negative impacts on human health and the environment (Naranjo and Ellsworth, 2009).

Agricultural sustainability refers to the ability of agricultural systems to maintain or enhance productivity and ecosystem health over the long term while ensuring economic viability and social equity. It encompasses practices and strategies that promote efficient resource utilization, minimize negative environmental impacts, such as soil degradation and water pollution, conserve biodiversity, and support resilient farming communities (Wijaya and Glasbergen, 2016).

The presented study investigated the impact of various plant protection methods on achieving agricultural sustainability in Iraq (Figure 1). Additionally, it sought to assess the socio-economic implications of adopting sustainable plant protection measures and their potential for long-term viability within the Iraqi agricultural context (Naranjo and Ellsworth, 2009). The latest findings will provide valuable insights into the efficacy of different plant protection methods in Iraq and their potential to contribute to agricultural sustainability (Gill and Goyal, 2016). The study addresses the vital issues of achieving Iraqi agricultural sustainability through applied research regarding the impact of plant protection methods (Naranjo and Ellsworth, 2009).

The paper comprised an introduction, presented the theoretical framework and hypotheses, materials and methods, measures, and sections on data analysis, results, and the discussion. The study also tackled the theoretical implications of the findings, practical contributions for stakeholders, and its limitations.

Theory and hypotheses

- The chief hypothesis of this study (H1): There is a close relationship between plant protection methods and achieving agricultural sustainability.
- The null hypothesis (H0): No relationship existed between plant protection methods and achieving agricultural sustainability.

Hypothesis (H2): There is a significant (*P* ≤ 0.05) effect of the implementation of Integrated Pest Management (IPM) practices on agricultural systems in achieving agricultural sustainability.

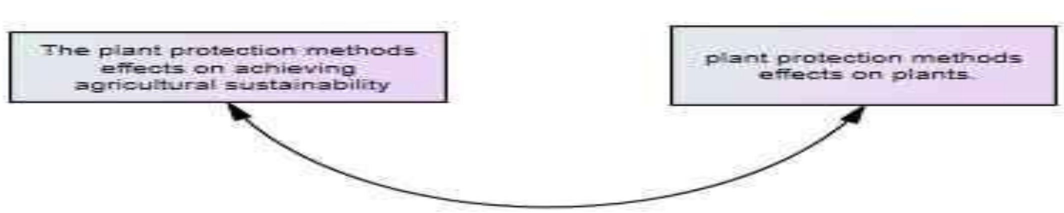

Figure 1. The Model.

- Hypothesis (H3): There is a significant (*P* ≤ 0.05) effect of biological control practices on agricultural systems in achieving agricultural sustainability.
- Hypothesis (H4): There is a significant (*P* ≤ 0.05) effect of the genetic resistance practices in agricultural systems in achieving agricultural sustainability.
- Hypothesis (H5): There is a significant (*P* ≤ 0.05) effect of the cultural practices in agricultural systems in achieving agricultural sustainability.
- Hypothesis (H6): There is a significant (*P* ≤ 0.05) effect of physical barriers and traps in agricultural systems in achieving agricultural sustainability.
- Hypothesis (H7): There is a significant (*P* ≤ 0.05) effect of the Precision Agriculture Technologies in agricultural systems in achieving agricultural sustainability.

Plant protection methods

Plant protection methods are crucial in safeguarding crops from the detrimental impacts of pests, diseases, and weeds and ensuring sustainable agricultural production. As the world population constantly rises, an increasing demand for food, fiber, and other agricultural products prevails (Jennings, 2022). However, the constant threats to the ability to meet these food demands by various biotic and abiotic factors can considerably affect crop health and productivity. The pertinent study presents an overview of some randomly selected modern methods of plant protection to recognize their effects on achieving agricultural sustainability (Nath and Saikia, 2022).

Integrated pest management (IPM)

Integrated pest management (IPM) aims to minimize the use of chemical pesticides while effectively controlling pests in agricultural systems (Gill and Goyal, 2016). IPM emphasizes the use of environment-friendly and sustainable pest management practices. Integrating targeted chemical interventions is a chief aspect of IPM (Gill and Goya, 2016). The concept of Integrated Control (ICC) (Ster *et al*., 1959) has led to the widely accepted notion of IPM, which has been a globally recognized approach to control pests effectively for over 50 years (Naranjo and Ellsworth, 2009). IPM, as shown below, has a specific design for whitefly control (Ellsworth and Martinez-Carrillo, 2001):

Insects

- *Anisolabis maritima* (Dermaptera: Anisolabididae): Attacks the eggs, larvae, and pupae of *Rhynchophorus ferrugineus* in Saudi Arabia.
- *Chelisoches morio* (Dermaptera: Chelisochidae): Attacks the eggs, and larvae of *R. ferrugineus* in India.

Mites

- *Aegyptus alhassa* (Mesostigmata: Trachyuropodidae): Attacks the eggs, pupae, and adults of *R. ferrugineus* in Saudi Arabia.
- *Aegyptus rynchophorus*: Attacks the pupae and adults of *R. ferrugineus* in Egypt.

In summary, IPM implementation reduces the reliance on chemical pesticides, promotes ecosystem health, enhances crop productivity and resilience, and contributes to economic viability. By adopting IPM, farmers can effectively manage pests and diseases while minimizing environmental impact and ensuring agricultural systems' long-term sustainability.

Biological control

Biological control has been a widely recognized and effective method in pest management worldwide, and its importance has grown alongside the development of IPM practices (Orr, 2009). Natural enemies are crucial in regulating pest populations, making biological control a fundamental component of IPM strategies (O'Neil *et al.,* 2003). However, when implementing IPM programs, it is vital to consider employing specific tactics, as different control methods interact with one another (Orr, 2009).

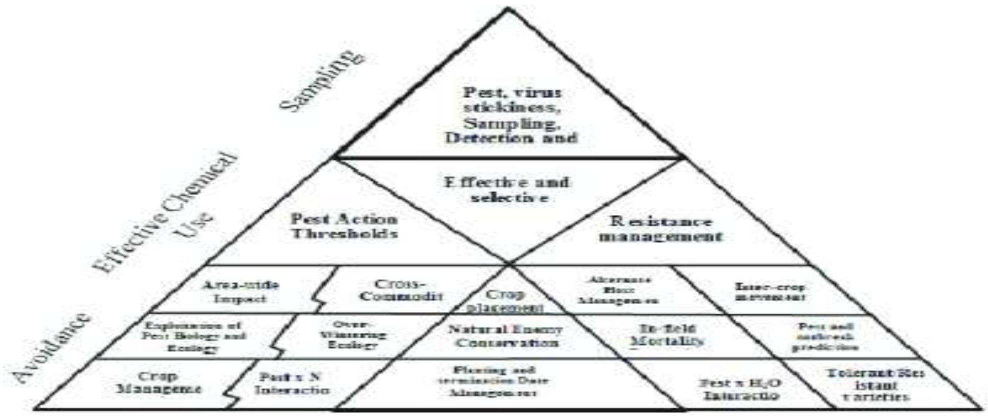

Figure 2. A conceptual diagram of whitefly IPM (Ellsworth, 2001).

Despite the advantages of biological control and IPM, both approaches have encountered hindrances due to limited biological data and the lack of knowledge required to develop economically, environmentally, and socially sustainable crop and animal production systems (Tauber *et al.,* 1985).

The red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (*Coleoptera: Curculionidae*), is a well-known pest that causes significant damage to coconut plantations (*Cocos nucifera*). Past studies compiled a list of insects and mites that serve as natural enemies of *R. ferrugineus* worldwide (Figure 2) (Murphy and Briscoe, 1999). The list reveals that the most diverse insect groups belong to *Diptera* (four species) and *Dermaptera* (three species), while the dominant group among mites is Mesostigmata (Mazza *et al.,* 2014). (Hypothesis H3)

Genetic resistance

Genetic resistance is a pest management strategy that involves developing and using crop varieties possessing inherent resistance to specific insect pests and diseases. This approach is achievable through traditional breeding techniques and genetic modification (Bajwa and Kogan, 2003). Genetic modification (GM) allows for more precise and targeted variations to the crop's genetic makeup compared with traditional breeding (Van-Esse *et al.,* 2019). The goal of genetic resistance is to reduce the reliance on chemical pesticides by equipping crops with built-in defense system against pests.

Some illustrations of genetic strategies are presently accessible for managing diseases caused by bacterial, viral, fungal, and oomycete pathogens. These approaches involve employing genetic modifications to enhance crop resistance against such pathogens. By introducing specific genetic factors, the new genotypes' creation can be better equipped to combat infections and diseases caused by these microorganisms. These genetic solutions for diseases offer promising avenues for protecting crops and mitigating the impact of bacterial, viral, fungal, and oomycete pathogens in agriculture.

- Point of Intervention: Pathogen Perception

GM Technology: Modification of NLRs (Nucleotide-binding domain leucine-rich repeat) (Maqbool *et al.,* 2015)

- Point of Intervention: Pathogen Perception

GM Technology: NLR protease trap (Kim *et al.,* 2016)

- Point of Intervention: Pathogen Perception

GM Technology: NLR resurrection (Wu *et al.,* 2017)

- Point of Intervention: Pathogen Effect or Binding

GM Technology: Modification of effect or binding sites (Zhang *et al.,* 2015)

By searching previous studies, the researchers think that genetic resistance contributes to agricultural sustainability in three ways, i.e., reduced chemical pesticide use, enhanced resource efficiency, and decreased production costs. Overall, by integrating genetic resistance into farming practices, one can foster a more sustainable and resilient agricultural system for the future. (Hypothesis H4)

Cultural practices

In general, cultural practices in sustainable plant disease management refer to agricultural practices that focus on preventive measures and manipulating plant environment and cultural practices to reduce the occurrence and severity of plant diseases. These practices can include crop rotation, intercropping, cover cropping, trap cropping, and employing resistant plant varieties (Niwas *et al.,* 2021). **(Hypothesis H5)**

Physical barriers and traps

A physical barrier is a structure made of various materials, such as wood, metal, plastic, or even living organisms, used to enclose an area. The concept of physical barriers originally had associated negative attributes versus chemical insecticides for efficiency and application methods. However, with the emergence of IPM as a crucial aspect of sustainable agriculture, physical barriers became more positively viewed. These barriers are often compatible with alternative methods and insecticides, making them IPM strategies' valuable component. (Hypothesis H6)

Precision agriculture technologies

Precision agriculture technologies offer a data-driven and site-specific approach to agricultural management, allowing farmers to optimize resource allocation, enhance productivity, and minimize environmental impact (Zhang *et al.,* 2002). (Hypothesis H7)

Agricultural sustainability

Naturally, agricultural sustainability refers to practically managing agricultural resources by meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves balancing economic viability, environmental stewardship, and social responsibility within the agriculture system. Agricultural sustainability implementation requires a holistic approach that considers interactions between different components of the agriculture system (Schaller, 1993). By adopting sustainable practices, agriculture can contribute to environmental conservation, food security, and the well-being of farmers and rural communities while minimizing its negative impacts on the planet.

MATERIALS AND METHODS

The independent variable is plant protection methods, and the dependent variable is agriculture sustainability. In determining the study hypotheses mentioned above, the study field was agriculture, and the study community was some colleges of Mosul University, Iraq, with the research samples comprising farmers randomly chosen to maintain neutrality and impartiality.

The study method used a survey to analyze using a questionnaire as the study tool. The data processing utilized the statistical analysis program SPSS and Amos, processing the measurement tools using descriptive analyses, i.e., frequencies, percentages, means, and standard deviation, and inferential statistical analyses, such as linear correlation and simple linear regression. The five-way Likert method adoption helped in formulating the questions in the survey questionnaire, with an estimated balance adopted according to the five-way Likert division scale (mean 1:1.79 = public attitude strongly disagrees, mean 1.80:2.59 = public attitude disagrees, mean 2.60:3.39 = public attitude neutral, mean 3.40:4.19 = public attitude agrees, and mean 4.20:5 = public attitude strongly agrees).

The questionnaire, split into two axes, had the first axis (from v1:v3) concerned with the demographic characteristics of the samples, while the second axis (from v4:v11) was on the relationship between plant protection methods and achieving agriculture sustainability. The reliability statistics (alpha = 92%) mean the questionnaire was fair and reliable. In Iraq, the farmers participated in this exploratory study via a survey. Fifty-five farmers (N = 55) completed the survey and became part of the final analysis.

Measures

The study used three questions to measure the demographic information and eight questions to measure the relation between plant protection methods and achieving agriculture sustainability, which had ratings on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) and scale (Cronbach's Alpha = 0.92) refers to the Reliability Statistics.

Data analysis

The descriptive analyses included frequencies, percentages, mean, and standard deviation to analyze the demographic axis. Aside from mean averages, these analyses further verified the public attitude to all the survey questions. About inferential statistical analyses, the simple linear correlation assessed the study hypotheses. The simple linear regression also analyzed the main hypotheses. The Amos program helped verify the relationship between the dependent and the independent variables.

RESULTS

The demographic axis

Of the participants, 44 (80.0%) were men (Cumulative percent [cp] = 80.0%), and 11 (20.0%) were women (cp = 100.0%). About age, 0 (0.0%) was between 20–30 (cp = 0.0%), eight (14.5%) were between 31–40 (cp = 14.5%), 26 (47.3%) were between 41–50 (cp = 61.8%), 21 (38.2%) were 51 and above (cp = 100.0%).

About years of experience, three (5.5%) were between 0–5 (cp = 5.5%), one (1.8%) was between 6–10 (cp = 7.3%), 10 (18.2%) were between 11–15 (cp = 25.5%), 19 (34.5%) were between 16–20 (cp = 60%), 11 (20%) were between 21–25 (cp = 80%), and 11 (20%) were 26 and above (cp = 100.0%).

The frequencies, percentages, means, and standard deviation

Based on the descriptive statistics (Table 1), the following information were evident.

- Plant protection methods: Most respondents (45.5%) strongly agree, followed by 45.5% who agreed, indicating a positive attitude toward the effects of plant protection methods on crop plants.
- Integrated Pest Management (IPM) practices: Again, most (45.5%) farmers strongly agreed, with 41.8% agreeing, suggesting that respondents have a positive perception of the effects of IPM practices on plants.
- Biological control practices: A significant portion (47.3%) of respondents agree, while 40% strongly agree, indicating a generally positive attitude toward the effects of biological control practices on plants.
- Genetic resistance practices: Similar to the previous categories, a considerable proportion (45.5%) agree, and 41.8% strongly agreed, suggesting a positive perception of the effects of genetic resistance practices on crop plants.
- Cultural practices: Most respondents (49.1%) agree, while 38.2% strongly agree, indicating a favorable attitude toward the effects of cultural practices on crop plants.
- Physical barriers and traps: The distribution was at par with the previous categories, with 45.5% agreeing and 41.8% strongly agreeing, demonstrating a positive relationship between the effects of physical barriers and traps on plants.
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Table 1. The frequencies, percentages, means, and standard deviation of the career decision.

Descriptive Statistics								
Questions	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagreed (%)	Means	Std. Deviation	Public attitude
Plant protection methods' effects on plants.	19 (34.5)	30 (45.5)	3 (5.5)	1 (1.8)	2 (3.6)	4.1455	.89065	Agree
The implementation of Integrated Pest Management (IPM) practices' effects on plants.	25 (45.5)	23 (41.8)	3 (5.5)	2 (3.6)	2 (3.6)	4.2182	.97546	Strongly agree
Biological control practices' effects on plants.	22 (40)	26 (47.3)	3 (5.5)	2 (3.6)	2 (3.6)	4.1636	.95769	Agree
Genetic resistance practices' effect on plants.	23 (41.8)	25 (45.5)	3 (5.5)	1 (1.8)	3 (5.5)	4.1636	1.01404	Agree
Cultural practices' effects on plants.	21 (38.2)	27 (49.1)	3 (5.5)	3 (5.5)	1 (1.8)	4.1636	.89781	Agree
Physical barriers and traps' effects on plants.	23 (41.8)	25 (45.5)	3 (5.5)	1 (1.8)	3 (5.5)	4.1636	1.01404	Agree
Precision Agriculture Technologies' effects on plants.	23 (41.8)	26 (47.3)	2 (3.6)	2 (3.6)	2 (3.6)	4.2000	.95063	Strongly agree
The plant protection methods' effects on achieving agricultural sustainability	31 (56.4)	17 (30.9)	3 (5.5)	1 (1.8)	3 (5.5)	4.3091	1.05185	Strongly agree
The public attitude for work intentions								Agree

- Precision Agriculture Technologies: Both agreement (47.3%) and strong agreement (41.8%) were prevalent, indicating a positive attitude toward the effects of precision agriculture technologies on plants.
- Plant protection methods and agricultural sustainability: Most respondents (56.4%) strongly agree, with 30.9% agreeing, suggesting a firm belief in the positive effects of plant protection methods on achieving agricultural sustainability.

The confirmatory factor analysis

The confirmatory factor analysis results for all factors were above 88% (Figure 3), which revealed a high correlation of observed variables with their corresponding latent factors. However, the model fits the data well, with the factors capturing a large proportion of the variance in the observed variables.

The simple liner correlation analysis

The linear correlation analysis for the research hypotheses (2 to 7) proceeded according to the theoretical framework. The results measurement followed the method according to the Likert five scale ($R = 0$ = Non-existent, $0.00<R<0.25$ = weak, $0.26<R<0.75$ = medium, $0.76<R<1$ = strong, $R = 1$ = complete) and through the analysis of hypothesis 1. The correlation coefficient ($r = 0.86$) exhibited means, indicating significantly positive ($a = 0.01$, 1-tailed). It proves the null hypothesis (hypothesis H0) was baseless and rejects it. Proving the validity of the research's main hypothesis (hypothesis H1) through the analysis of hypothesis 2, showed the correlation coefficient ($r = 0.85$), which according to the scale, the correlation was significantly positive ($a = 0.01$, 1-tailed). Through the analysis of hypothesis 3, the correlation coefficient ($r = 0.858$) enunciated a considerably positive correlation, according to the scale ($a = 0.01$, 1-tailed).

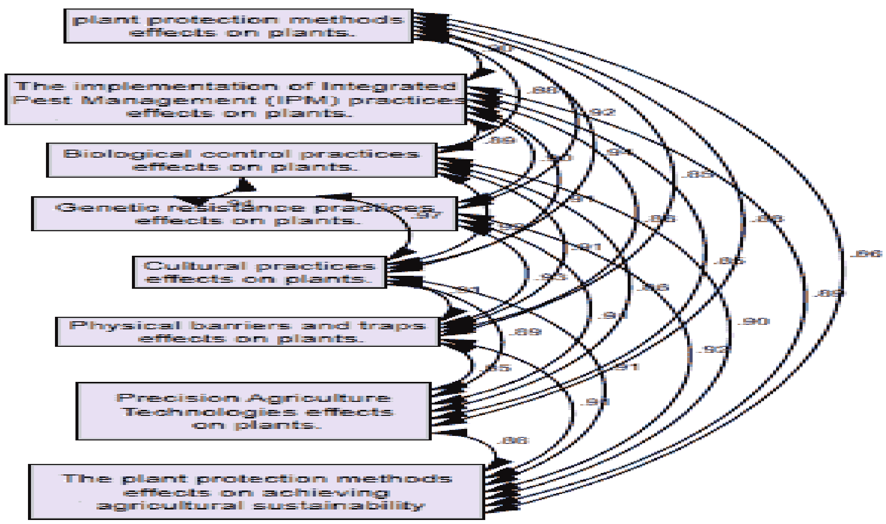

Figure 3. The confirmatory factor analysis.

The result revealed through the analysis of hypothesis 4 that the correlation coefficient (r = 0.924) was significantly positive (a = 0.01, 1-tailed). The analysis of hypothesis 5 revealed that the correlation coefficient (r = 0.906) was substantially positive (a = 0.01, 1-tailed). From hypothesis 6 analysis, the correlation coefficient (r = 0.907) was meaningfully positive (a = 0.01, 1-tailed). As for hypothesis 7 analysis, it revealed that the correlation coefficient (r = 0.863) was notably positive (a = 0.01, 1-tailed).

The simple liner regression analysis

The linear regression analysis progressed on the first and main hypothesis, with the analysis results provided in Table 2. By extrapolating, it was evident that Sig. = 0.000b and was less than 0.01%, which means denying H0 and accepting H1. It revealed a significant regression between the independent and the dependent variables. About the coefficient test and by extrapolating the equation of linear regression analysis (y = b0 + b1x) substituting into the equation (Table 3), the output was y = 0.097+1.052x, which revealed that the independent variable varied by 1%, and the dependent variable varied by 1.52%.

The AMOS analysis

The previous model showed that whenever the independent variable changes by 1.00, the dependent variable varies by 0.73, confirming the positive effect of plant protection methods on agricultural sustainability (Figure 4). The estimate of regression weight when working, the passion goes up by 1, work intentions go up by 0.729 (S.E. value), and the regression weight estimate (0.729) has a standard error of about 0.059 (Table 4).

C.R. value: Dividing the regression weight estimate by its standard error gives the value (z = 0.729 / 0.059 = 12.407). In other words, the regression weight estimates were 12.407 standard errors above zero. P value: The probability of getting a critical ratio as large as 12.407 in absolute value, which was less than 0.001. The regression weight for plant protection methods in the prediction of achieving agriculture sustainability was significantly different from zero at the 0.001 level (two-tailed***), which means that the model was perfect.

By extrapolating Table 5, CMIN (Chi-Square Minimum Discrepancy) means that the default model has a discrepancy of 0.000, meaning the model was fit; df means (df = d =

Table 2. Analysis of variance (ANOVA) of various variables.

ANOVA[a]						
Model		Sum of squares	Df	Mean square	F	Significant
	Regression	44.229	1	44.229	151.079	0.000[b]
1	Residual	15.516	53	.293		
	Total	59.745	54			

a. Dependent Variable: The plant protection methods' effects on achieving agricultural sustainability
b. Predictors: (Constant), plant protection methods' effects on plants

Table 3. The coefficients test.

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	0.097	0.350		0.276	0.783
1	Plant protection methods' effects on plants	1.016	0.083	0.860	12.291	0.000

a. Dependent Variable: The plant protection methods' effects on achieving agricultural sustainability

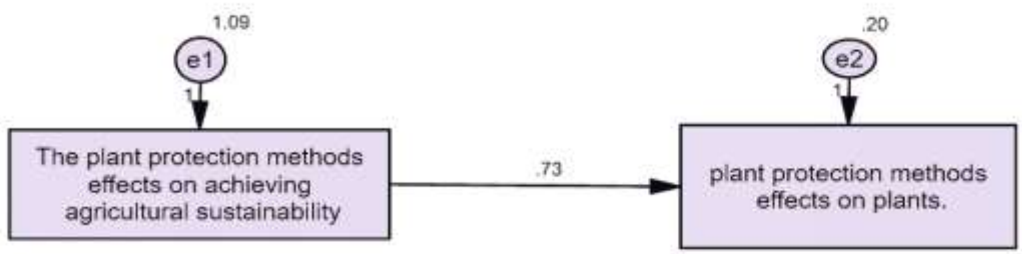

Figure 4. The Amos Model.

Table 4. Estimates for regression weights from the Amos model.

	Estimate	S.E.	C.R.	P	Label
V4 <--- v11	0.729	0.059	12.407	***	

Table 5. Model Fit Summary of the Amos model.

Model	CMIN	DF	RMR	GFI	NFI (Delta1)	IFI(Delta2)	CFI	Chi-square
Default model	0.000	0.000	0.000	1.000	1.000	1.000	1.000	0.000

p-q = 0.000), which means that the model has 0 degrees of freedom. An RMR of zero indicates a perfect fit, and the GFI was less or equal to 1. A value of 1 indicates a perfect fit. NFI means normed fit index = 1.000; IFI means incremental fit index = 1.000. CFI (Comparative Fit Index) values close to one indicate a superb fit because Chi-square = 0.000. No counting for RMSEA (Root Mean Square Error of Approximation) occurred. Based on these results, all the values specified that the model of the relationship between plant protection methods in the prediction and achieving agriculture sustainability was valid as the best model, and all indicators revealed the degree of strength.

DISCUSSION

The intellectual outcome of the relevant study presides in this section. The primary purpose was to examine the relationship between plant protection methods in predicting and achieving agricultural sustainability (Niwas *et al*., 2021). The results showed that plant protection methods performed well in achieving agricultural sustainability (Maqbool *et al*., 2015).

Based on the theoretical proposals within the global and Arabian studies, it was evident that a considerable lack of interest in this topic existed, especially in Iraq (Zhang *et al*., 2015). Although, all previous investigations showed concern about studying plant protection methods. However, all these studies were not recent and not exhaustive of all the aspects of the two variables (Kim *et al*., 2016). The recent study dealt with the relationship between the two variables more deeply than other studies. The said study added the outcomes of this relationship, making it the first comprehensive integrated study of the relationship between the two variables (Wu *et al*., 2017; Nawaz *et al*., 2022; Osman *et al*., 2023).

Theoretical implications

This study has several theoretical implications. First, it contributes to the existing body of knowledge on the relationship between plant protection methods and agricultural sustainability, particularly in the context of Iraq. By examining the effectiveness, economic viability, and socio-environmental implications of these methods, the study provides valuable insights into how different plant protection strategies can affect the agricultural systems' long-term sustainability. The presented research also expands our understanding of the factors that influence agricultural productivity, economic viability, and environmental sustainability.

Second, the study adds to the theoretical understanding of the adoption of sustainable agricultural practices. By investigating the socio-economic factors that influence the adoption rates of sustainable plant protection methods, the research sheds light on the barriers and facilitators of adoption. This knowledge can further form the theoretical frameworks related to technology adoption, behavioral change, and decision-making processes in the agriculture sector.

Practical contributions

This study also offers several practical contributions. Firstly, the findings can guide policymakers and agriculture stakeholders in developing evidence-based strategies and policies to promote sustainable plant protection measures in Iraq. Secondly, the study has practical implications for agronomists and the farming community by providing them with information on the performance and benefits of various plant protection procedures.

Limitations and future research directions

Despite the contributions, the presented study has certain limitations that require addressing:

- Firstly, future research could expand the study scope to include a broader range of countries to enhance the external validity of the findings.
- Secondly, future research could incorporate objective measures, such as field observations and laboratory analyses.
- Finally, future studies could explore the interplay between plant protection methods and other related factors.

CONCLUSIONS

The findings provide practical guidance for policymakers, agronomists, and farmers to enhance agricultural productivity, economic viability, and environmental sustainability. Despite limitations in geographical focus and data reliance, the presented study explored opportunities for future research to expand and deepen the understanding of sustainable plant protection practices. By addressing these limitations and exploring related factors, future research can further advance knowledge and contribute to developing sustainable agricultural systems worldwide.

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