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Drivers of farmers' intention to adopt integrated pest management: a case study of vegetable farmers in Pakistan

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Abstract. Integrated pest management adoption is quite low around the globe, particularly in developing countries, due to different factors. Here, we examine the factors affecting the intention of Pakistani farmers to adopt integrated pest management practices in vegetable production using a structured questionnaire. We interviewed 301 vegetable growers in Multan, Pakistan. The reliability and validity of the data, along with the underlying relationship between the observed variables, were identified through exploratory factor analysis. The majority of the farmers (79.4%) relied on pesticides for pest control. More than four out of 10 of the respondents (43.8%) reported that okra received the highest application of pesticides followed by potato (24.5%) and cauliflower (17.9%). Integrated pest management was currently nonexistent among the vegetable growers of the study area. The latent factors—"knowledge of the adverse effects of pesticide," "belief in the efficacy of non-chemical pest control measures," "perceived barriers to the adoption of integrated pest management," "progressive farming approach," and "intention to adopt integrated pest management"—were subsequently confirmed using confirmatory factor analysis. The structural equation model suggested that the intention to adopt integrated pest management is significantly affected by farmers' knowledge of the adverse effects of pesticides ($\beta = 0.274$, z-value = 3.082, $P = 0.002$). An increase in farmers' awareness of the harmful effects of pesticides could lead to integrated pest management adoption for pest control. The scale for intention to adopt integrated pest management developed in this study can be used in future studies and provide valuable insights to the policymakers for devising integrated pest management adoption campaigns in the study area.

Key words: integrated pest management; Pakistan; pesticides; structural equation model; vegetables.

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Introduction

Increasing global population drives a growing food demand and poses a considerable challenge to the agricultural production systems (Ash et al. 2010). Despite growing pesticide use for pest control, global crop losses due to pests have not decreased significantly (Oerke 2006). In addition, pest invasions are predicted to increase in frequency and severity in the future due to agricultural intensification (Bernal and Medina 2018), climate change (Phophi et al. 2020), and trade globalization (Perrings et al. 2005). As an alternative to continuing reliance on pesticides, integrated pest management emerged as a pest control strategy in the 1960s. Integrated pest management is currently practiced in various cropping systems and is endorsed globally by relevant stakeholders. The definition of integrated pest management centers on sustainable, cost-effective, and eco-friendly management of pests (Ehler 2006). Recently, integrated pest management has been studied in terms of management, business, and sustainability aspects, involving host plant resistance, and cultural, mechanical, biological, microbial, and chemical management options (Dara 2019). Despite its strong suitability for low input agriculture, integrated pest management has a weak adoption record in developing countries, raising questions on its applicability (Orr 2003, Sadique Rahman 2020, Rahman 2021). Understanding the adoption of integrated pest management calls for a direct interaction with indigenous stakeholders (Parsa et al. 2014); however, most research focusing on poor integrated pest management adoption originates from the developed countries (Morse and Buhler 1997).

Alongside the positive commercial importance of pesticides as a management tool, many harmful environmental impacts of their application on non-target organisms, food webs, and ecosystem functioning have been identified (Joseph 2019). Horticultural crops frequently contain a higher percentage of detectable pesticide residues (Mehmood et al. 2020). The dietary intake of vegetables is considered a significant exposure pathway of the general population to pesticide residues, especially in developing countries (Lehmann et al. 2017, Omwenga et al. 2021). Integrated pest management aims to employ an "ecosystem approach," which encapsulates different pest and disease control methods used in combination to minimize pesticide use (FAO 2017). Its wider adoption in horticulture in developing countries is expected to reduce pesticide exposure of growers and consumers (Hossain et al. 2017). An oft-cited reason for the ineffectiveness of agriculture policy is the failure to incorporate stakeholders' perspectives in the policymaking process (Khan et al. 2021, Chilombo and Van Der Horst 2021). Here, evidence suggests that understanding the factors that underpin farmers' attitude toward integrated pest management is critical to effective campaigning for integrated pest management adoption (Rezaei et al. 2020).

Relatively little is known about farmers' attitudes toward and intention to adopt integrated pest management in developing countries. This study uses the context of Pakistani smallholder growers to generate and evaluate evidence on this issue. Pakistan is a developing country where agriculture contributes 18.5% to the gross domestic product and engages 38.5% of the national labor force (Rehman et al. 2019). Out of 22.2 million hectares (ha) of the total crop production area, 4.5 million ha is used to grow fruits and vegetable crops (FAO 2006). Pakistani farmers are increasingly relying on pesticides to manage agricultural pests and maintain crop yield (Khan and Damalas 2015*a*, Damalas and Khan 2017, Khan et al. 2021). Numerous pesticides are routinely applied to manage crop pests in the country (Tahir et al. 2001), but the overuse of pesticides has resulted in detectable health and environmental consequences (Tariq et al. 2007). This study aims at exploring the key factors that influence Pakistani farmers' intention to adopt integrated pest management, with the view of informing policy supporting its wider application in the country.

Theoretical framework

In developing countries, farmers are over-reliant on synthetic pesticides to manage pests (Schreinemachers et al. 2017). A similar trend has been reported in Pakistan, where the farmers are heavily dependent on synthetic pesticides to manage crop pests (Khan and Damalas 2015*b*, Schreinemachers et al. 2017). Among many other consequences, the overuse of pesticides leads to environmental and human health risks (Khan et al. 2021, Lovison Sasso et al. 2021). Therefore, the adoption of alternate pest control methods is an important part of the wider attempt to reduce pesticide use and encourage sustainable agricultural production. Integrated pest management targets a more practical implementation of different pest control options designed to supplement, minimize, or substitute synthetic pesticide application (Pretty and Bharucha 2015). The pest management aspect of integrated pest management utilizes multiple options, such as host plant resistance (e.g., use of resistant and tolerant cultivars to manage crop pests), behavioral control (e.g., modifying the pest behavior through bait traps, mating disruption), physical or mechanical control (e.g., use of light and sticky traps, regular destruction of damaged vegetables at each harvest), biological control (e.g., the release of natural enemies including predators and parasitoids), microbial control (e.g., the use of entomopathogenic fungi, bacteria, nematodes), cultural control (e.g., good agronomic practices, such as destruction of crop debris and weeds, timely planting), and chemical control (e.g., use of synthetic chemical pesticides) (Dara 2019).

Understanding farmers' intention to adopt integrated pest management is complex since many factors can affect farmers' intention, which, in turn, is a strong determinant of future adoption behavior. Evidence suggests that farmers' knowledge of non-chemical pest control options is critical to reducing pesticide use and adopting integrated pest management practices. The adoption of integrated pest management is a non-conventional approach for farmers in developing countries. Farmers who understand non-chemical pest management options are more likely to adopt them and reduce the use of pesticides (Gautam et al. 2017).

Life risks are strong motivations for farmers to reduce pesticide use and turn to alternatives (Rijal et al. 2018). Farmers aware of the harmful effects of pesticides show interest in learning about available alternatives for managing pests and implementing integrated pest management (Hashemi and Damalas 2010). A study from Pakistan also suggests that awareness of pesticide use risks could increase farmers' willingness to pay for safer management options (Hashemi and Damalas 2010). Farmers' knowledge of the harmful effects of pesticides could influence the adoption of biological control, an important component of integrated pest management (Abdollahzadeh et al. 2015). In addition to human health, farmers' understanding of how pesticide overuse can damage livestock and environmental resources could also affect their decision to rationalize the use of pesticides. Pesticide residues affect domesticated animals, including cows, buffalos (Sajid et al. 2016), and poultry birds (Aulakh et al. 2006). Farmers who know the harmful effects of pesticides on the environment and biodiversity appear to be cautious in using pesticides (Sharifzadeh et al. 2018).

Provision of training and information on integrated pest management methods is frequently seen as a critical factor in integrated pest management adoption, especially in developing countries. Training farmers improves their knowledge to explore different non-chemical options and reduces their dependence on pesticides (Damalas and Koutroubas 2017). A recent study from Punjab, Pakistan, highlighted integrated pest management training as a critical determinant of farmers' pesticide risk perception (Mehmood et al. 2020). Training through farmer field schools has been reported to encourage integrated pest management adoption, as the trained farmers adopted biological control and reduced pesticide use (Ali and Sharif 2012). Researchers have used a "knowledge deficit" model to explain this phenomenon, which suggests that people are not adopting an important practice because they lack the awareness or expertise, whereas if they have information and training, they are more likely to change their behavior (Niles et al. 2016, Zakaria et al. 2020, Chilombo and Van Der Horst 2021). Several barriers to the adoption of integrated pest management in developing countries have been reported, for example, lack of technical support and training to farmers, unfavorable government policies, low education levels, limited access to integrated pest management inputs, to name a few (Parsa et al. 2014). Therefore, it is essential to consider the barriers to integrated pest management adoption while designing integrated pest management promotion plans for a farming community.

In developing countries, farmers' progressiveness plays a vital role in adopting non-conventional farming practices (Khan et al. 2021).

Research showed that progressive farmers are more likely to adopt integrated pest management (Allahyari et al. 2016) because they are less afraid of changing their conventional farming methods and are more open to the new technologies, information, and trainings imparted by the extension workers. A study from Pakistan also found farmers' progressive approach to be a key determinant of integrated pest management adoption in cotton crops (Hussain et al. 2011).

Hypothesis development

In the present study, the following determinants of integrated pest management adoption intention were identified, based on pre-study survey outcome and factor analysis: (1) knowledge of the adverse effects of pesticides, (2) progressive farming approach, (3) belief in the efficacy of non-chemical pest control options, and (4) perceived barriers to integrated pest management adoption. We aimed to determine the relative importance of these factors toward integrated pest management adoption in vegetable production in Pakistan and tested the following set of hypotheses:

H_1: Knowledge of the adverse effects of pesticides affects the intention to adopt integrated pest management.
H_2: Perceived barriers to integrated pest management adoption affect the intention to adopt integrated pest management.
H_3: Progressive farming approach affects the intention to adopt integrated pest management.
H_4: Belief in the efficacy of non-chemical pest control options affects the intention to adopt integrated pest management.

Methodology

Study area

Data collection was carried out in the Multan division, located in the southern parts of Punjab Province, Pakistan. The study area has an arid tropical climate characterized by long and hot summers (Ahmad et al. 2014). The region is part of the Indus plain where fertile soils support the production of mainly cotton, wheat, and rice—but also many other crop types. This region has a pesticide use history going back more than 50 yr (Khan et al. 2015). Some of the most commonly grown vegetables include okra, potato, brinjal, cauliflower, and chilies.

Questionnaire design

We used a structured questionnaire-based survey method to collect data in this study. This method allows for the collection of a relatively large number of responses in a short time (Vishwakarma et al. 2018). Based on a detailed review of the literature (Syed et al. 2014, Schreinemachers et al. 2017, Akter et al. 2018, Rezaei et al. 2018, Mubushar et al. 2019), a set of 24 questions was prepared for the first draft of the questionnaire. These questions primarily belonged to the following six areas:

1. How well do farmers understand the adverse effects of pesticides on human health?
2. How well do farmers know the harmful effects of pesticides on the environment and livestock?
3. What are the perceived barriers to integrated pest management adoption for farmers?
4. How well is the provision of integrated pest management services and training to farmers in the study area?
5. How likely are farmers to adopt non-traditional concepts in farming, that is, how progressive farmers are?
6. How well do farmers understand the usefulness of non-chemical pest control options?

The questionnaire was then discussed with agriculture extension workers and university faculty members. We pre-tested and validated the questionnaire through a pilot study consisting of 40 respondents. Following the pilot study, necessary amendments were made in the language and structure of the questions to improve clarity and understanding. The final questionnaire had 17 questions arranged into seven parts: demographic information, farming practices, progressive farming approach (PFA), knowledge of the adverse effects of pesticides (AEP), belief in the efficacy of non-chemical pest control options (EPM), perceived barriers to the adoption of integrated pest management (IPM), and integrated pest management adoption behavior (INT). Responses to all items in parts 3–7 of the questionnaire were recorded on a 5-point Likert scale, from 1 = strongly disagree to 5 = strongly agree (see Appendix S1 for full questionnaire).

Six graduate students from the MNS University of Agriculture and Bahauddin Zakariya University Multan were trained to conduct this survey study. The students had previous experience of similar surveys and understood the subject well. The surveyors explained to the farmers the purpose of this survey and defined integrated pest management prior to the interview. In addition, it was made clear to the farmers that the focus of the survey was insecticides rather than herbicides or fungicides.

Sample size and data collection

We used a structural equation modeling (SEM) framework to test our hypothesis. There is no consensus on sample size for SEM-based studies. Some researchers suggest a minimum sample size of 200, while others recommend a sample size of 5–10 respondents per item in the questionnaire for a conceptually clear structure for factor analysis. Since we had 17 items in our questionnaire, a minimum sample size of 170 was required for factor analysis in this study. We collected responses of 301 respondents in this study, between January and March 2020. All the farmers interviewed were male because females are rarely involved in pesticide use-related and other on-farm decisions in the study area.

Exploratory factor analysis

We used factor analysis to summarize data in a way that inter-relationships among observed variables and patterns can be easily understood. Exploratory factor analysis (EFA) is used to "discover the number of factors influencing variables and to analyze which variables go together."

Step I: Correlation analysis.—We used a correlation matrix to examine the strength of the intercorrelations among the 17 items. Pearson's correlation coefficients showed bivariate relationships between the different dimensions. In addition, we used Bartlett's test of sphericity, which compares the correlation matrix of the observed data with an identity matrix. Rejection of the null hypothesis of the test signifies that the variables are correlated.

Step II: Sample adequacy test.—Before conducting the factor analysis, we used the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) to assess the suitability of our data for structure detection. The KMO test "measures sampling adequacy for each variable in the model and the complete model." KMO returns values between 0 and 1; high values indicate that factor analysis may be useful. If the value is above 0.6, the data are considered adequate for factor analysis.

Step III: Factor extraction.—Several methods are reported in the literature for determining the minimum number of factors to be extracted. One of the most commonly employed methods is the K1 rule, retaining the factors having eigenvalues >1. Alternatively, the examination of the scree plot and retaining factors above the elbow point or the parallel analysis can be used. Most studies rely on one or two of these methods; we, however, used all three methods to ensure the best possible model fit and accurate interpretation of retained factors. We used "minres" (minimum residual) factoring method and "oblimin" rotation to extract the number of factors as determined by the three methods mentioned above. We only included the items that had a factor loading of more than 0.5, which shows high convergence.

Confirmatory factor analysis

To test the EFA model's fit to our data, we used a confirmatory factor analysis (CFA) approach followed by SEM. Confirmatory factor analysis estimates how well the model based on the empirically revealed factors fits the data and offers further analysis of structural relations between the factors. We randomly split the data into two halves for EFA and CFA. A CFA generally involves four key steps: testing internal reliability, convergent and divergent validity, and assessing model fit. A brief description of these steps is given as follows:

Step I: Internal reliability test.—Internal consistency of each of the six constructs is evaluated by Cronbach's alpha, which indicates how closely a set of items are related. Cronbach's alpha value of 0.7 and above reflects that the dimensions considered are reliable, that is, internally consistent.

Step II: Convergent validity.—Convergent validity is the measure of the correlation of different items of the same factor that are in agreement. To assess the convergent validity in this study, we followed the standard protocol of average variance extracted (AVE) value threshold; AVE value of above 0.5 indicates adequate convergent validity (Fornell and Larcker 1981).

Step III: Discriminant validity.—Discriminant validity (also known as divergent validity) is the assessment of the degree to which a construct or factor does not correlate with other constructs or factors from which it is supposed to diverge. To test for discriminant validity, we followed the criterion suggested by Fornell-Lacker (Ab Hamid et al. 2017); we compared the AVE with the squared correlation between latent factors. A latent factor is expected to explain better the variance of its own items rather than the variance of other factors. Thus, AVE of each factor should be greater than the squared correlations with other latent constructs (Shao and Ünal 2019).

Step IV: Assessment of model fit.—Chi-square statistic of the likelihood-ratio test is a commonly reported measure of model fit. A P-value >0.05 indicates a good fit of the model. However, in most cases where the sample size is large, the chi-square statistic value is almost always <0.05 (Jacobs et al. 2018). Thus, a more suitable criterion is chi-square statistic-to-degrees of freedom ratio (λ^2/df), which indicates a good fit if the ratio is below 5 (Cangur and Ercan 2015). Also, we used comparative fit index (CFI), Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA) to assess how well our model fits the data. For CFI and TLI, values >0.9 indicate a reasonable fit. For RMSEA, value below 0.08 indicates an "acceptable fit," while values below 0.05 suggest a "good fit" (Maasoumi et al. 2017).

Structural equation model.—Factor analysis is followed by SEM (Hughes et al. 1986, Hair et al. 1998), which is a multivariate statistical technique employed to examine structural relationships between measured or observed variables and latent constructs or factors. SEM can be seen as a combination of factor analysis and multiple linear regression analysis. We used SEM to test our hypothesis (H_1–H_4). The conceptual model for this study is presented in Fig. 1. All statistical

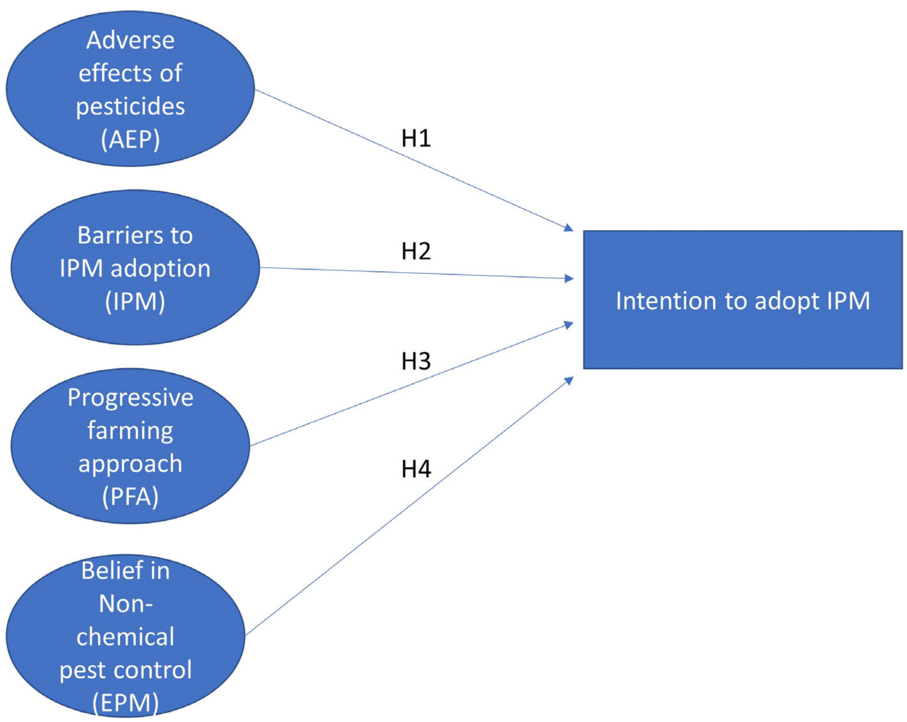

Fig. 1. Conceptual model (intention to adopt integrated pest management). H_1–H_4 show the four hypotheses of this study.

analyses were carried out using R statistical software (R Foundation for Statistical Computing, Vienna, Austria) and Statistical Package for the Social Sciences (SPSS), version 21 (IBM Corp., Armonk, NY, USA).

Results

Demographic characteristics of the respondents

All the 301 respondents interviewed for this study were male. The majority of the respondents (38.5%) were aged above 50 yr followed by those between 35 and 50 yr (29.9%). More than two-thirds of the respondents were either illiterate or had a primary level of education. The most common farm size was <5 acres (34.7%), while only 13.9% had a farm size of more than 20 acres (Table 1). More than half of the respondents (64%) had a farming experience of more than ten years. Table 1 shows the detailed demographic characteristics of the respondents. The most frequently grown vegetable in the study area is okra, followed by potato, carrot, onion, spinach, and cauliflower (Fig. 2a). Furthermore, okra received the highest application of pesticides, followed by potato, cauliflower, peas, bitter gourd, taro root, and spinach (Fig. 2b). Most of the farmers surveyed relied on chemical control as a primary measure for controlling insect pests, followed by those who used a combination of cultural and chemical control measures (Fig. 2c).

Table 1. Demographic characteristics of the respondents (number and percentage of respondents in the parenthesis, $n = 301$).

Demographic characteristics	Number (%)
Education	
Illiterate	113 (37.5)
Primary school	94 (31.2)
High school	72 (23.9)
Vocational training	15 (4.9)
University graduate	7 (2.3)
Farm size	
Up to 5 acres	104 (34.7)
6–10 acres	81 (26.8)
10–20 acres	74 (24.5)
More than 20 acres	42 (13.9)
Gender	
Male	301 (100)
Female	0 (0)
Age	
Up to 25 yr	55 (18.2)
25–35 yr	40 (13.2)
35–50 yr	90 (29.9)
More than 50 yr	116 (38.5)
Farming experience	
Up to 5 yr	48 (16.2)
6–10 yr	61 (20.1)
11–20 yr	89 (29.5)
More than 20 yr	103 (34.1)

Exploratory factor analysis

The KMO measurement of sampling adequacy was 0.78, and the results of Bartlett's test was significant (Bartlett's $K^2 = 51.11$, df = 16, $P < 0.001$), indicating that our data set was suitable for EFA. K1 rule, parallel analysis, and scree plot method suggested a minimum of five factors in the data. The visualization of the correlation matrix (Appendix S2) suggested the presence of 4–5 factors in the data set. This step was followed by factor extraction, including 17 items with a factor loading of more than 0.5 (Vishwakarma et al. 2018; Table 2). In total, the five factors explained 60.36% variance in the data (Table 3).

Confirmatory factor analysis

As shown in Table 2, except for "Intention" (0.79), Cronbach's α for all constructs was higher than 0.8, which suggests a good internal consistency. We also found evidence of acceptable convergent validity as the total average variance (AVE) was 0.56. The AVE value of each factor was greater than the squared correlations with other latent constructs, suggesting acceptable discriminant validity (Table 4). Furthermore, the values of CFI (0.934), TLI (0.914), RMSEA (0.07), and λ^2/df (1.74) suggest a reasonable fit of the model (Table 5).

Structural equation model

We tested the hypotheses H_1–H_4 using a structural equation model. The results of the linear regression analysis suggested that there is no evidence to support hypotheses H_2, H_3, and H_4, but hypothesis H_1 is supported (Table 6). The factor AEP (knowledge of the adverse effects of pesticides) significantly predicted the intention to adopt integrated pest management ($\beta = 0.274$, z-value = 3.082, $P = 0.002$). Fig. 3 shows the path diagram representing the measurement model

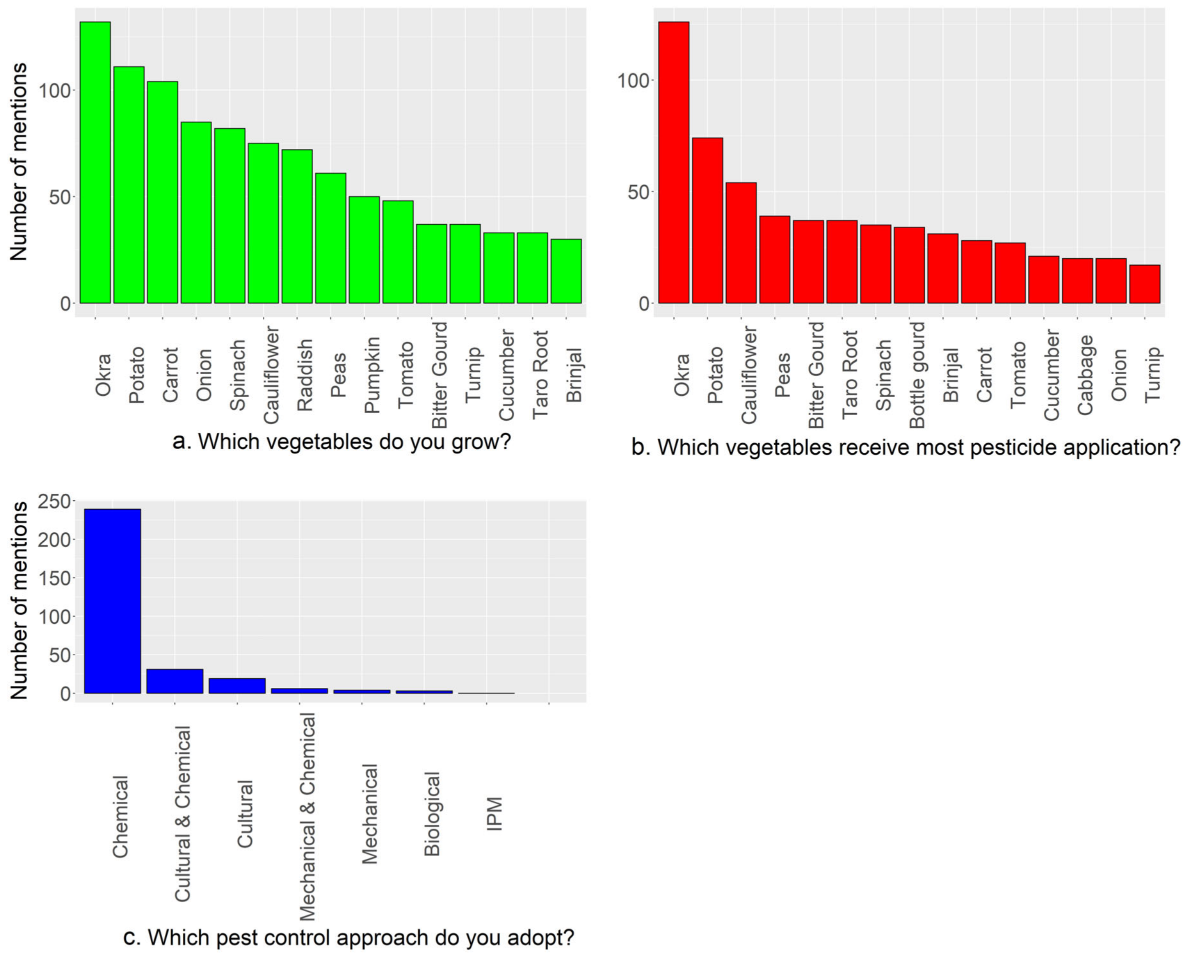

Fig. 2. (a) Top 15 terms given in response to the question, “Which vegetables do you grow?” and, (b) “which vegetables receive the most pesticide application?” (c) Number of mentions for different pest control methods in response to the question, “which pest control approach do you adopt?”.

and the structural equation model showing standardized parameter estimates.

Discussion

The present study aims to investigate the current status of pest control measures among vegetable growers in southern Punjab, Pakistan, and develop a statistical model to explore the potential of different factors that are likely to affect farmers’ intention to adopt integrated pest management practices. Knowledge of the adverse effects of pesticides significantly affected vegetable farmers’ intention to adopt integrated pest management. This finding agrees with previous studies, which confirm a relationship between farmers’ knowledge about harmful effects of pesticides and their intention to adopt alternate pest control options (Allahyari et al. 2017).

Globally, pesticide use has doubled in the last three decades and has been expected to continue as a management tool to control pests (Reddy 2016). Farmers in developing countries are overly dependent on pesticides to manage agricultural pests (Schreinemachers et al. 2017). In Pakistan, the use of pesticides has increased significantly over the past years (Tariq et al. 2007). Recent studies suggest that lack of training and

Table 2. Questions/items included in the questionnaire, the mean and standard deviation of response to each question, revised ID's of the items based on how they converged to a single latent factor in exploratory factor analysis, and Cronbach's alpha for each construct of items.

Item ID	Questions/Items	Mean (SD)	Revised ID
Item 1	How frequently do you listen/watch programs or read literature on farming?	1.89 (0.89)	PFA1
Item 2	How frequently do you attend meetings with agricultural extension workers?	2.13 (1.04)	PFA2
Item 3	How frequently do you attend technical training on farming?	2.04 (1.0)	PFA3
Item 4	Pesticides are harmful to human health	3.68 (1.0)	AEP1
Item 5	Pesticides adversely affect the livestock	3.99 (1.8)	AEP2
Item 6	Pesticides have adverse effects on the environment	3.87 (0.83)	AEP3
Item 7	Cultural control is effective for pest control	2.49 (1.0)	EPM1
Item 8	Mechanical control is effective for pest control	2.29 (1.04)	EPM2
Item 9	Biological control is effective for pest control	2.54 (1.08)	EPM3
Item 10	Adoption of integrated pest management would cost money	2.87 (0.98)	IPM1
Item 11	The adoption of integrated pest management would not control pests as good as chemical control	2.98 (0.95)	IPM2
Item 12	Lack of training is a barrier towards adopting integrated pest management	2.84 (0.95)	IPM3
Item 13	I plan to seek more information on the use of integrated pest management	3.97 (0.80)	INT1
Item 14	I plan to adopt the integrated pest management practices to reduce the dependence on the pesticides	3.98 (0.90)	INT2
Item 15	I plan to use integrated pest management as it leads to the betterment of the environment	3.88 (0.80)	INT3
Item 16	I plan to use integrated pest management as it is easy to adapt to for me	3.91 (0.81)	INT4
Item 17	I plan to use integrated pest management as it reduces the cost of pesticides	3.97 (0.81)	INT5

Notes: PFA, progressive farming approach; AEP, knowledge of the adverse effects of pesticide; EPM, belief in the efficacy of non-chemical pest control methods; IPM, barriers to IPM adoption; INT, intention to adopt. Cronbach's alpha values for each latent factor are as follows: PFA = 0.83, AEP = 0.8, EPM = 0.79, IPM = 0.82, and INT = 0.82.

awareness about integrated pest management often pushes farmers toward irrational pesticide use (Ahmad et al. 2019).

Integrated pest management offers the opportunity to decrease the use of pesticides. However, farmers in developing countries face numerous obstacles in adopting the standard integrated pest management practices. Insufficient knowledge, lack of supportive policies, lower literacy levels, traditional over-dependence on pesticides, and inadequate integrated pest management training are the most cited obstacles to integrated pest management adoption in the developing world (Parsa et al. 2014). Moreover, farmers often assume that integrated pest management is complicated and challenging to be implemented on a large scale (Timprasert et al. 2014). Due to these assumptions, farmers in developing countries rely on a single technology, primarily pesticides, to manage crop pests (Ecobichon 2001). A study covering four African countries reports several reasons for farmers' over-reliance on pesticides, including lack of training in other pest management options, use of susceptible cultivars, competitive pressure, and inadequate knowledge of pest control economics (Williamson et al. 2008). Farmers in three countries of South-East Asia reported that strong belief in pesticide effectiveness and influence of commercial pesticide dealers are critical factors of choosing the chemical pest control measures (Schreinemachers et al. 2017). Farmers' training in integrated pest management is crucial and leads to lower pesticide use; a study in Bangladesh found that integrated pest management adoption leads to decreased pesticide use among trained vegetable farmers (Gautam et al. 2017).

The intention of farmers in Pakistan to adopt integrated pest management could be influenced by their knowledge of the adverse effect of pesticides. This is a rather indirect variable—its usage assumes that the more farmers know that pesticides are harmful, the more likely they are to turn to safer options. However, the knowledge of the pesticide use risks is linked with a thorough understanding of the concept, rather than a general awareness of pesticides (Damalas and Koutroubas 2018). Farmers' awareness of the adverse effects of pesticides on human health is critical to reducing pesticide use and adopting integrated

Table 3. Factor loadings in exploratory factor analysis (extraction method = "minimum residual," rotation = "oblimin") and variance explained by each latent factor.

Item	Factor loading
INT	
1	0.50
2	0.737
3	0.52
4	0.665
5	0.625
EPM	
6	0.796
7	0.823
8	0.65
AEP	
9	0.599
10	0.919
11	0.709
PFA	
12	0.717
13	0.605
14	0.874
IPM	
15	0.742
16	0.794
17	0.766

Notes: INT, intention to adopt integrated pest management; EPM, belief in the efficacy of non-chemical pest control methods; AEP, knowledge of the adverse effects of pesticide; PFA, progressive farming approach; IPM, barriers to IPM adoption. Variance explained by each latent factor is as follows: INT = 11.95%; EPM = 12.4%; AEP = 12.1%; PFA = 11.23%; and IPM = 12.68%. The total variance explained is 60.36%.

pest management methods to control insect pests. In developing countries, 10–15% of farmers experience lethal exposures to pesticides. Developing countries utilize 20% of global pesticides, but suffer 99% of deaths due to pesticide poisonings (Jeyaratnam and Chia 1994).

Table 5. Model fit summary for confirmatory factor analysis.

Parameter	Value
λ^2/df	1.73
CFI	0.934
TLI	0.914
RMSEA	0.07

Notes: Parameter abbreviations are as follows: λ^2/df, chi-square statistic-to-degrees of freedom ratio; CFI, comparative fit index; TLI, Tucker-Lewis index; RMSEA, root mean square error of approximation.

Table 6. Result of linear regression in structural equation model.

Variable	Estimate	SE	*z*	*P*
PFA	0.05	0.104	0.484	0.628
IPM	−0.085	0.09	−0.945	0.345
AEP	0.274	0.089	3.082	0.002
EPM	−0.095	0.117	−0.813	0.416

Notes: The response variable, INT (intention to adopt integrated pest management), is predicted by PFA (progressive farming approach), IPM (barriers to IPM adoption), AEP (knowledge of the adverse effects of pesticide), and EPM (belief in the efficacy of non-chemical pest control methods). SE, standard error.

Surprisingly, in our study, this indirect variable is a significant factor likely to affect farmer behavior, whereas direct factors such as perceived barriers to integrated pest management were not significant. Elsewhere, farmers who received integrated pest management training, including the adverse effects of pesticides, switched to less pesticide use and safer handling (Jørs et al. 2016). Similarly, a study in Nepal showed that farmers' pesticide knowledge has a vital role in community integrated pest management implementation (Atreya 2007). Integrated pest management adoption by Thai vegetable

Table 4. Average variance (AVE), correlation with, and squared correlations between factors (in parentheses).

Measure	AVE	PFA	AEP	INT	IPM	EPM
PFA	0.63	1				
AEP	0.59	−0.25 (0.06)	1			
INT	0.41	−0.16 (0.02)	0.55 (0.302)	1		
IPM	0.55	0.63 (0.396)	−0.17 (0.028)	−0.14 (0.019)	1	
EPM	0.63	0.61 (0.372)	−0.49 (0.24)	−0.28 (0.078)	0.51 (0.26)	1

Notes: PFA, progressive farming approach; AEP, knowledge of the adverse effects of pesticide; INT, intention to adopt integrated pest management; IPM, barriers to IPM adoption; EPM, belief in the efficacy of non-chemical pest control methods.

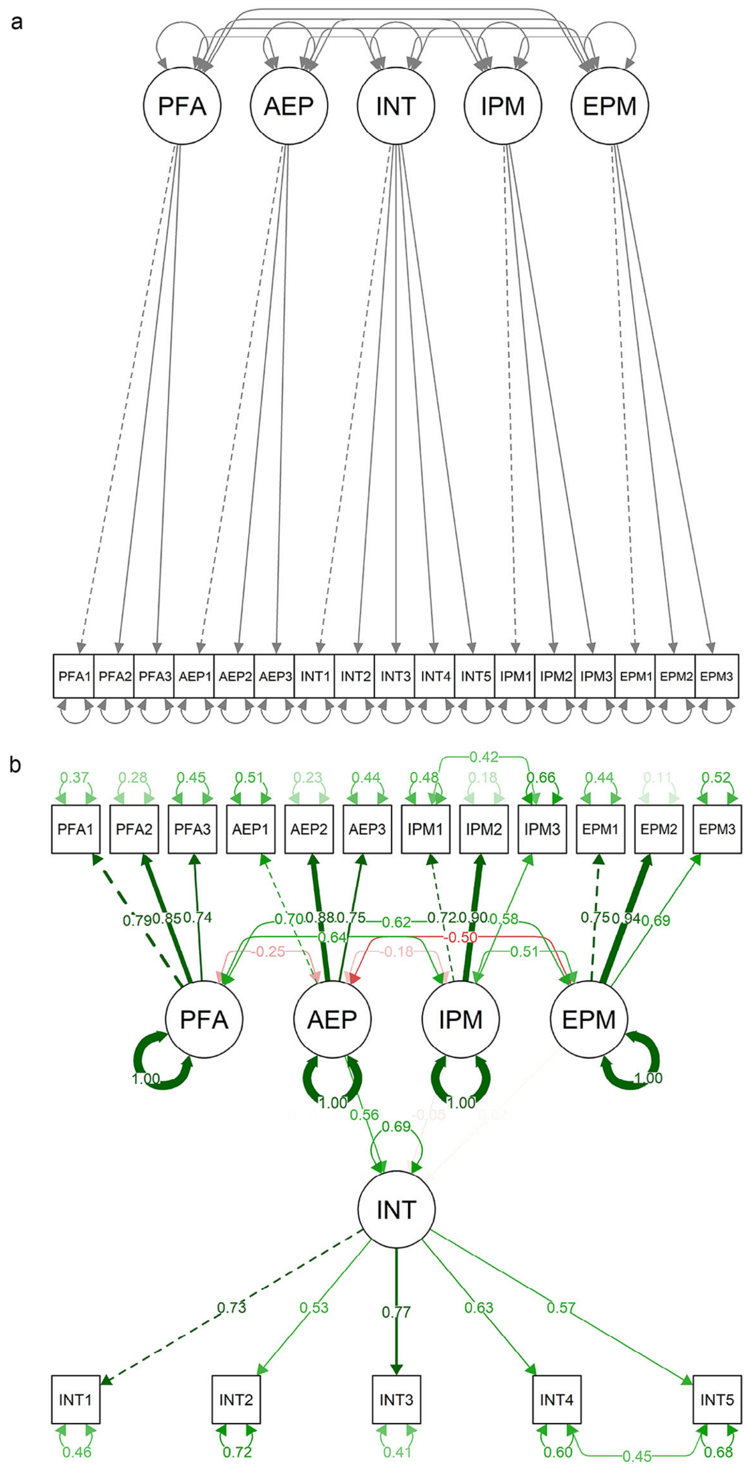

Fig. 3. (a) Path diagram representing the measurement model, and (b) structural equation model showing standardized parameter estimates. PFA, progressive farming approach; AEP, knowledge of the adverse effects of pesticides; INT, intention to adopt integrated pest management; IPM, barriers to integrated pest management adoption; EPM, belief in the efficacy of non-chemical pest control methods.

farmers is influenced by the knowledge of pesticide harmful effects on humans and the environment (Timprasert et al. 2014). However, farmers' knowledge of the adverse effects of pesticides is not the only factor affecting integrated pest management adoption. Evidence suggests the economic loss due to pests overtakes the concerns about the health and environmental consequences of pesticide use. Conversely, there is evidence that highlighting the economic benefits of integrated pest management emanating from reduced spend on pesticides compounds the effect of training on the adverse effects of pesticides (Hruska and Corriols 2002).

Educating farmers about the adverse effects of pesticides (Barrón Cuenca et al. 2019), along with a well-designed integrated pest management awareness program highlighting its economic, social, and environmental benefits, could result in improved integrated pest management adoption rates. Factoring in the identified obstacles to integrated pest management adoption could help design suitable extension programs effective in developing countries. The outcomes of this study may help improve integrated pest management adoption, leading to maintained or increased agricultural yield with smaller costs to health and the environment.

This study is the first report on the trends of pest control tools used by vegetable farmers in southern Punjab, Pakistan. For the first time, the study also reports the degree of pesticide application on vegetable crops grown in the study area. Most importantly, our study presents a robust statistical model that tests the potential of some of the most important determinants of integrated pest management adoption. The results of this study are unique and offer opportunities for future investigations. For example, "perceived barriers" is often a strong determinant of an individual's intention; our results, however, demonstrate that perceived barriers to integrated pest management did not affect farmers' intention to adopt integrated pest management. Similarly, belief in the efficacy of non-chemical pest control options is usually expected to be a significant predictor of integrated pest management adoption, but the results of the present study suggested otherwise. These trends indicate that predictors of farmers' intention to adopt an intervention could significantly vary with socioeconomic profiles, study areas, and many other unexplored underlying factors. From this point of view, this study is an important addition to the available literature on this subject. It highlights the importance of educating farmers about the harmful effects of pesticides, which could persuade them to adopt non-chemical pest control options.

We acknowledge some limitations to this study that need to be addressed in future research. First, this study focused only on vegetable growers in the southern region of Punjab province. The socioeconomic profile of the farmers and regional agroclimatic conditions are distinct from other provinces in the country. Thus, the results of this study should not be generalized to the entire country without further investigations. Second, the questionnaire used in this study was kept short but well targeted to issues specific to the area, yielding a data set suitable only for some analyses. We recommend future studies to build on our results and use more sophisticated theoretical models, such as the theory of planned behavior, innovation diffusion theory, trans-theoretical model, and technology acceptance model to investigate farmers' intention to adopt integrated pest management in different parts of the country. Third, we did not consider the direct or mediation effects of socioeconomic variables on the response variables; for example, the socioeconomic profile of the farmers in the structural equation model could yield interesting results in future studies.

It is important to consider that this study explores the intention of farmers to adopt integrated pest management and concludes that the farmers aware of health risks associated with pesticide use showed greater intention to adopt integrated pest management approaches. This is in line with previous reports, which suggest people who have knowledge about health risks associated with a product or practice are more likely to adopt alternate products or practices (Hansen et al. 2003). Intention is considered the most important determinant of a person's behavior in the future since intention suggests how much the individual attempts to perform the behavior. A strong intention therefore leads to engagement in that behavior. However, it is important to consider that the stated intention may not always be the same as "actual adoption" (Niles et al. 2016). Sometimes, farmers may overstate their intention because they want to look as though they are good stewards of the land and intend to do the right thing. Therefore, future studies comparing intention vs. actual behavior for integrated pest management adoption could reveal more interesting results on this subject.

Conclusion

This study, for the first time, explores the determinants of integrated pest management adoption in the farming community of southern Punjab, Pakistan. We believe that this study has several useful implications. First, the study is useful for those studying farmers' behavior, as it enhances the existing scientific literature regarding factors influencing farmers' intention to rationalize the use of pesticides and adopt integrated pest management. Second, the proposed model offers empirical evidence of the factors that affect farmers' intention to adopt integrated pest management, demonstrating the potential of these variables to influence farmers' choices in the future. Third, we believe that the results of this study are helpful for policymakers to design policies and campaigns to reduce over-reliance on pesticides and adopt integrated pest management practices. We conclude that integrated pest management is currently non-existent among the vegetable growers of the study area. Farmers can be motivated to adopt integrated pest management by educating them about the adverse effects of pesticide overuse. The study emphasizes the need to promote integrated pest management in vegetable growers, as over-reliance on pesticides can potentially harm the environment and the health of the general population.

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Data Availability

Data are available from Dryad: https://doi.org/10.5061/dryad.qrfj6q5g3

Supporting Information

Additional Supporting Information may be found online at: http://onlinelibrary.wiley.com/doi/10.1002/ecs2.3812/full