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Factors Predicting Tomato Farmers' Safety Behavior in Iran: Presenting an Integrated Model (Theory of Planned Behavior and Health Belief Model)

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Abstract:

In recent years, the increase in both the prevalence and resistance of tomato pests in Ardabil Province, Iran, has significantly raised the rate of pesticide use. Therefore, the main objective of this study was to identify the predictive factors of safety behavior (SB) in the use of chemical pesticides among tomato farmers in northwestern Iran (Ardabil Province). An integrated model combining the Theory of Planned Behavior (TPB) and the Health Belief Model (HBM) was evaluated to predict farmers' SB across four stages: purchase and storage, preparation, application, and post-application of pesticides. The sample size (n = 310) was determined using a multi-stage random sampling method among tomato growers in Parsabad (173), Meshginshahr (91), and Kowsar (46) counties. The results showed that the majority of farmers (31.94%) exhibited relatively unsafe behavior. According to structural equation modeling findings, although the measurement models of both TPB and the integrated model showed acceptable fit, the integrated model (with 63% explanatory power) had a better fit and higher predictive power than the TPB model (with 52%). Therefore, the integrated model provides a stronger framework than the TPB or HBM alone for estimating farmers' SB at all four stages, especially during the "application of pesticides" stage. Moreover, improving farmers' cues to action and perceived behavioral control through educational programs and mass and print media can significantly enhance their intentions and lead to positive changes in safety behavior.

Keywords: Pesticides, Safety Behavior, Theory of Planned Behavior, Health Belief Model, Tomato.

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INTRODUCTION

Weeds, pests, and diseases are showing increasing resistance to agricultural pesticides, leading farmers and farm workers to apply pesticides more frequently or use more toxic formulations (Rezaei et al., 2023; Qin & Lu, 2020; Sharifzadeh et al., 2019). Additionally, supportive programs in the agricultural sector aimed at boosting production (Chen, 2023; Sookhtanlou & Allahyari, 2021) and increasing financial gains have contributed to greater pesticide use by farmers (Righettini & Bordinm, 2023; Mazloomy Mahmoodabad et al., 2019). Although developing countries, on average, account for only a quarter of global pesticide consumption, they experience 99 percent of pesticide-related deaths, particularly among farm workers (Sookhtanlou & Allahyari, 2021; Diliarosta & Hardinata, 2019; Heeb et al., 2019). The unsafe use of pesticides decreases the efficiency and functional capacity of farmers, farm workers, their families, the environment, and public health (Rezaei et al., 2020; Afshari et al., 2018), as they may face high costs for hospitalization, medical services, and lost working days (Sookhtanlou et al., 2022; Kuhn et al., 2022).

SB refers to the set of measures taken by individuals to maintain and enhance safety and avoid health risks in their working environment (Sookhtanlou et al., 2022; Li et al., 2019). Tomato (*Solanum lycopersicum L.*) is the most important crop in Ardabil Province (northwestern Iran), but the recent increase in crop pests has led to a growing health crisis among farmers. Afshari et al. (2018) reported that 60.3 percent of pesticide users in western Iran suffer from pesticide poisoning. In recent years, a decline in the quality of imported pesticides and a rise in crop pests have been reported across many parts of Iran. For example, an increase in tomato pests in the Ardabil Plain and in rice pests has led to a rise in chemical pesticide use in the northern and northwestern regions of the country (Bagheri et al., 2019; Rezaei et al., 2020; Sharifzadeh et al., 2018). Clearly, improving SB and protecting farmers' health depend heavily on psychological factors and individual behaviors (Sharifzadeh et al., 2018). Therefore, various studies have employed behavioral models—primarily HBM and TPB—to examine farmers' SB, and in some cases, extended models have been used by incorporating additional variables (Bagheri et al., 2019; Hartley et al., 2018; Liu et al., 2020; Rezaei et al., 2020; Wang et al., 2019; Yuen et al., 2020).

The integration or extension of certain models can enhance their effectiveness (Liu et al., 2020; Wang et al., 2019; Yuen et al., 2020). For example, Rezaei et al. (2020) and Bagheri et al. (2019) found that adding specific variables to a base model (TPB) increased its efficiency and explanatory power; however, the validation of such extended models often remains ambiguous. Moreover, many studies have primarily focused on measuring farmers' SB during the pesticide application stage, despite SB comprising four distinct stages: purchase and storage, preparation, application, and post-application (Bhandari et al., 2018; Diliarosta & Hardinata, 2019; Glanz et al., 2008; Jallow et al., 2017; Sharifzadeh et al., 2019; Sun et al., 2009). Bhandari et al. (2018) applied HBM to study farmers' SB and found that the perceived barriers variable had no effect. In contrast, Yuen et al. (2020), Wang et al. (2019), Mohebbi et al. (2019), Wright et al. (2019), and Moradhaseli et al. (2019) demonstrated that HBM components—self-efficacy, perceived barriers, susceptibility, benefits, severity, and cues to action—positively and significantly influenced farmers' SB. Conversely, Sadeghi et al. (2018) found that the HBM structure accounted for only 4 percent of the variance in preventive behavior related to self-medication. Wang et al. (2019) combined TPB and Protection Motivation Theory (PMT) to analyze farmers' environmental behavior and found that the integrated model had a better fit than either model alone. Hartley et al. (2018) theoretically proposed and validated a consolidated HBM–TPB model to enhance participation in a physical injury prevention program. Additionally, in a review of SB, Şimşekoğlu and Lajunen (2008) compared the performance of HBM, basic TPB, and extended TPB models, concluding that while the basic TPB model had an acceptable fit, the other two performed poorly. The findings of Mazloomy Mahmoodabad et al. (2019), Isin and Yildirim (2007), and Strong et al. (2008) also emphasized the importance of perceived severity and perceived susceptibility in influencing farmers' SB.

The TPB is a rational decision-making framework that explains a wide range of behaviors in specific contexts, including SB (Guerin & Toland, 2020; Peng & Chan, 2019). According to TPB, attitude, subjective norm, and perceived behavioral control are key variables that lead to behavioral intention, which in turn predicts SB (Ajzen, 1991; Kahramanoglu, 2020; Kim et al., 2013). *Attitude* refers to a predisposition to respond in a consistent (favorable or unfavorable) manner toward a situation, person, or object and reflects the positive or negative evaluation of a given behavior (Damalas & Koutroubas, 2018). *Subjective norm* relates to perceived social pressures that may influence a person to engage in or avoid a particular behavior (Bagheri et al., 2019; Kim et al., 2013). *Perceived behavioral control* refers to the perceived ease or difficulty of performing a behavior and the belief that the behavior is within the individual's capability (Kim et al., 2013; Wang et al., 2019).

According to the HBM, adopting correct health behaviors begins with individuals perceiving themselves as at risk (perceived susceptibility). They must then recognize the seriousness of the threat (perceived severity) and, upon evaluating potential benefits, engage in positive preventive behaviors (Bhandari et al., 2018; Jeihooni & Rakhshani, 2019; Rezaei et al., 2020; Yuen et al., 2020). The model also emphasizes that individuals need to believe that health or safety behaviors (SBs) are beneficial (perceived benefits) and that these benefits outweigh the perceived losses or costs (perceived barriers) (Bhandari et al., 2018; Moradhaseli et al., 2019). *Cues to action* serve as triggers that motivate behavior change, while *self-efficacy* refers to individuals' confidence in their ability to perform the behavior, which enhances SBs (Bhandari et al., 2018; Moradhaseli et al., 2019; Rezaei et al., 2020). Accordingly, this study aims to predict farmers' SB through an integrated and comprehensive model (HBM and TPB). Specifically, it seeks to examine whether the integrated model can effectively explain the process of SB adoption by tomato farmers in the use of chemical pesticides across four stages. The study pursues five objectives: (1) to measure farmers' SB levels in relation to chemical pesticide use; (2) to identify the priority information sources and SB stages in pesticide use; (3) to assess the predictive power and explanatory capacity of the integrated model, HBM, and TPB, and identify the optimal model;(4) to determine which stage of SB (purchase and storage, preparation, application, and post-application) is best explained by the optimal model; and (5) to identify the most important factors predicting farmers' SB in using chemical pesticides. The research background related to the conceptual model is summarized as follows:

HBM Components Influencing SB: The relationships

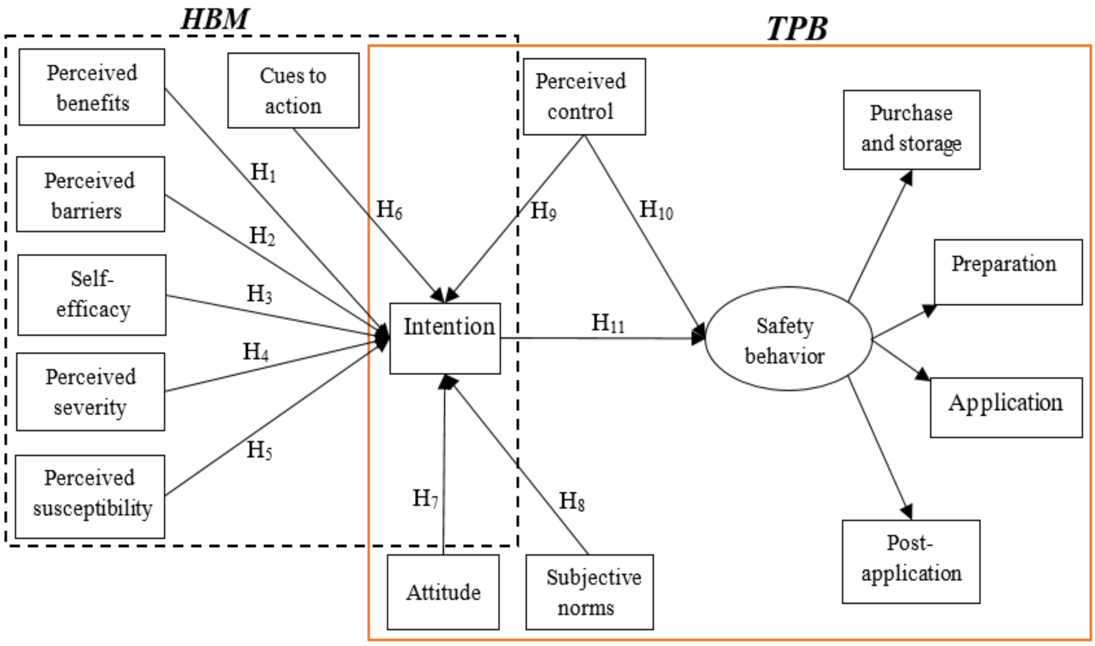

Figure 1. The Conceptual Model of the Study.

among perceived benefits, perceived barriers, perceived severity, perceived susceptibility, cues to action, and self-efficacy and their effects on SB were foundational to the conceptual model, based on findings from Yuen et al. (2020), Mazloomy Mahmoodabad et al. (2019), Wright et al. (2019), Moradhaseli et al. (2019), Mohebbi et al. (2019), Lamichhane et al. (2018), Bhandari et al. (2018), Sadeghi et al. (2018), and Ajzen (1991).

TPB Components Influencing SB: The effects of attitude, subjective norm, and perceived behavioral control on SB were incorporated into the model, based on the research of Brehmer (2023), Rezaei et al. (2020), Liu et al. (2020), Kahramanoglu (2020), Wang et al. (2019), Bagheri et al. (2019), Lamichhane et al. (2018), Jallow et al. (2017), Cevizci et al. (2015), Lekei et al. (2014), Strong et al. (2008), and Isin and Yildirim (2007).

Integration of HBM and TPB: Both models emphasize the role of intentions and beliefs in human behavior (Yuen et al., 2020). Given the extensive literature supporting each model in explaining SB, this study adopts an integrated approach, combining HBM and TPB into a comprehensive model to provide a more complete understanding of the SB process among farmers (Hartley et al., 2018; Macharia-Mutie et al., 2011; Sun et al., 2009; Yuen et al., 2020).

Stages of Farmers' SB: Farmers' SB is conceptualized across four stages: purchase and storage, preparation, application, and post-application (Bhandari et al., 2018; Diliarosta & Hardinata, 2019; Glanz et al., 2008; Sharifzadeh et al., 2019; Sun et al., 2009).

Accordingly, the conceptual model of the research is displayed in Figure 1 Overall, this study presents the following hypotheses:

H_1. Perceived benefits have significant predictive effect on farmers' intention towards using SB.

H_2. Perceived barriers have significant predictive effect on farmers' intention towards using SB.

H_3. Self-efficacy has significant predictive effect on farmers' intention towards using SB.

H_4. Perceived severity has significant predictive effect on farmers' intention towards using SB.

H_5. Perceived susceptibility has significant predictive effect on farmers' intention towards using SB.

H_6. Cues to action has significant predictive effect on farmers' intention towards using SB.

H_7. Farmers' attitude has significant predictive effect on farmers' intention towards using SB.

H_8. Subjective norms has significant predictive effect on farmers' intention towards using SB.

H_9 and H_{10}. Perceived behavioral control has significant predictive effect on farmers' intention and SB.

H_{11}. Intention has significant predictive effect on farmers' SB.

METODOLOGY

Ardabil Province, located in northwestern Iran, is a region with agriculturally fertile lands. Tomato (*Solanum lycopersicum L.*) is the most important crop in the province's vegetable production, with 5,578 hectares under tomato cultivation. This study is a descriptive, causal-correlational research conducted using a survey method. The statistical population included all active tomato farmers in Ardabil Province. Based on Bartlett et al.'s (2001) sample size table and a total population of 1,526 farmers, a sample size of 310 was determined. A multi-stage sampling technique was employed. In the first stage, three counties with significant tomato farming activity (Parsabad, Meshginshahr, and Kowsar) were selected. In the second stage, 14 villages were randomly chosen in proportion to the number of tomato farmers in each county (seven from Parsabad, four from Meshginshahr, and three from Kowsar). In the final stage, 310 farmers were randomly selected from these villages, proportionally distributed as 173 from Parsabad, 91 from Meshginshahr, and 46 from Kowsar.

Survey instrument

The survey instrument was a structured questionnaire consisting of four main sections. The first section gathered personal and professional (demographic) information about the tomato farmers. The second section included items related to pesticide use in tomato cultivation, the required quantities, and the sources of information used by farmers. The third section focused on safety behavior (SB) across four stages of chemical pesticide use, measured on a Likert scale ranging from 0 (never) to 5 (very high). The fourth section addressed the key variables influencing SB adoption. This section included TPB and HBM variables such as attitude toward pesticide application, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, behavioral intention, subjective norms, cues to action, perceived behavioral control, and self-efficacy (Rezaei et al., 2023; Chen, 2023; Brehmer, 2023; Kahramanoglu, 2020; Liu et al., 2020; Kahramanoglu et al., 2020; Mazloomy Mahmoodabad et al., 2019; Bagheri et al., 2019; Wright et al., 2019; Mohebbi et al., 2019; Sharifzadeh et al., 2019; Afshari et al., 2018; Jallow et al., 2017). The items measuring these variables were developed as an organized set of statements with a specific order and equal weights, using Likert scales ranging from 0 (nothing) to 5 (very high) and from 1 (completely disagree) to 5 (completely agree). Other items were formatted as open-ended or multiple-choice questions. To ensure validity, the questionnaire was reviewed by a panel of faculty members, experts from the Agricultural Jihad Organization of the province, and the Healthcare Center of Ardabil County, with their feedback incorporated through multiple revisions. Reliability was confirmed by Cronbach's alpha values exceeding 0.7 for the main research variables. For validating the structural equation model (Table 1), composite reliability (CR) and convergent validity were assessed. Convergent validity criteria included factor loadings ≥ 0.5, average variance extracted (AVE) ≥ 0.5, and composite reliability ≥ 0.7. All research variables had AVE values above 0.5 (Hair et al., 2010; Rezaei et al., 2020), confirming the appropriateness of the measurement model for analysis. Descriptions and assessments of reliability and validity for the main variables are presented in Table 1.

Table 1. Statistical Summary of Reliability and Construct Validity Analysis.

Latent variables (Abbreviation)	Indicators	Factor loading	Reliability and validity
Perceived severity (P. severity)	- Thinking about the side-effects of unsafe pesticide use frightens me.	0.741	CR= 0.701; AVE= 0.552; Cronbach's alpha= 0.694
	- If I am affected by the side-effects of chemical pesticides, it will be more dangerous than other diseases.	0.722	
	- If I suffer complications from the use of chemical inputs, my financial security will be jeopardized.	0.696	
	- The problems that I will experience from the consequences of unsafe behaviors are long-term.	0.781	
Perceived susceptibility (P. suscept)	- It is likely for me to be poisoned by chemical inputs.	0.754	CR= 0.822; AVE= 0.661; Cronbach's alpha= 0.770
	- My physical status makes me susceptible to be affected by the side-effects of chemical pesticides.	0.728	
	- Probably, in the future, the consequences of unsafe behavior in the farm will come to me (again).	0.853	
	- I get worried by not paying attention to safety behaviors on the farm.	0.812	
Attitude (Attitude)	- Unsafe use of pesticide in agriculture jeopardizes human health.	0.827	CR= 0.781; AVE= 0.673; Cronbach's alpha= 0.724
	- Unsafe use of pesticides contaminates underground and surface water bodies.	0.754	
	- Safety behavior measures are necessary and important to produce a healthier and safer product.	0.767	
	- Even if production costs increase, I will not compromise on safe practices.	0.812	
	- Producing a healthier and higher quality product has a higher priority than increasing production.	0.801	
Perceived benefits (P. benefits)	- By promoting safe behavior and health protection, I can make more financial saving.	0.746	CR= 0.733; AVE= 0.602; Cronbach's alpha= 0.701
	- Safe disposal of cans and pesticide residues can hinder threats to my health and the health of my family.	0.789	
	- Observing safety behavior on the farm will prevent my health problems in the future.	0.794	
	- Using safety equipment keeps me away from illness and the dangers of chemical inputs.	0.823	

Table 1. Statistical Summary of Reliability and Construct Validity Analysis. (continued).

Latent variables (Abbreviation)	**Indicators**	**Factor loading**	**Reliability and validity**
Perceived barriers (P. barriers)	- The protective equipment for pesticide use is expensive.	0.702	CR= 0.711; AVE= 0.562; Cronbach's alpha= 0.683
	- The use of protective equipment during pesticide application is time-consuming.	0.689	
	- The process of using safety behavior measures is complex.	0.712	
	- Safety behavior measures require the acquisition of many skills.	0.724	
	- Safety behavior measures require more manpower.	0.741	
Intention (Intention)	- I intend to reduce my pesticide dosage in future.	0.831	CR= 0.823; AVE= 0.663; Cronbach's alpha= 0.752
	- I intent to purchase and use appropriate protective equipment during pesticide use.	0.841	
	- I plan to use safer methods in the farm instead of using chemical inputs.	0.782	
	- In the future, I plan to make fundamental changes in the way of managing safety behavior in the farm.	0.711	
Cues to action (C. action)	- I do follow expert recommendations about safety rules.	0.762	CR= 0.773; AVE= 0.620; Cronbach's alpha= 0.722
	- I follow the TV and radio programs on the dangers of chemical pesticides.	0.731	
	- I read the instructions related to the use of chemical inputs before use.	0.789	
	- I use the experiences of skilled farmers in safety behaviors.	0.769	
	- I am looking to acquire more skills in applying safety methods in the farm.	0.754	
Self-efficacy (S. efficacy)	- I can keep the current crop yield with applying less pesticide.	0.704	CR= 0.713; AVE= 0.542; Cronbach's alpha= 0.692
	- I can use alternative methods in crop production.	0.721	
	- It is possible for me to prepare and use safety equipment and facilities to reduce unsafe behaviors in the farm.	0.727	
	- Taking action to reduce unsafe behaviors is possible for me in the farm.	0.719	
Perceived behavioral control (P. control)	- Applying safety behavior measures is uncomplicated for me.	0.732	CR= 0.790; AVE= 0.582; Cronbach's alpha= 0.683
	- It is easy for me to apply safety behavior measures in the farm.	0.701	
	- I have enough skills to easily implement safety measures in the farm.	0.757	
Subjective norms (S. norms)	- I care for the opinions of my friends and relatives when deciding on pesticide application	0.787	CR= 0.742; AVE= 0.591; Cronbach's alpha= 0.702
	- I prefer to use the dominant practices of other farmers in managing safety behavior on the farm.	0.708	
	- I consider the dominant opinions in the media and social networks about food safety management.	0.754	
	- If the people around me do not have a favorable opinion about my food safety management method, I will stop working.	0.795	
Purchase and storage (P. storage)	- Determining appropriate pesticide type for the pest and disease and checking its production and expiring dates.	0.827	CR= 0.813; AVE= 0.654; Cronbach's alpha= 0.763
	- Storing out of the reach of children and animals.	0.784	
	- Attending the recommendations of agricultural experts in selecting chemical pesticides	0.757	
	- Selecting and purchasing pesticides with lower risk hazards and more environmentally friendly.	0.732	
	- Purchasing from reliable pesticides stores.	0.716	
Preparation of pesticides (Preparation)	- Preparing pesticides outside the house.	0.846	CR= 0.761; AVE= 0.651; Cronbach's alpha= 0.712
	- Using protective equipment (gloves, mask, etc.) when solving or mixing pesticides.	0.827	
	- Attending the quality of soluble (water) or mixture in pesticide preparation.	0.752	
	- Learning how to prepare a mixture or solution of pesticide correctly.	0.767	
	- Reading instructions on the label of pesticides before use carefully	0.713	

Table 1. Statistical Summary of Reliability and Construct Validity Analysis. (continued).

Latent variables (Abbreviation)	Indicators	Factor loading	Reliability and validity
Application (Application)	- Using boots.	0.851	CR= 0.752; AVE= 0.663; Cronbach's alpha= 0.740
	- Avoiding pesticide spraying at adverse weather or in the opposite direction of wind.	0.848	
	- Using mask or a piece of cloth.	0.835	
	- Wearing safety glasses.	0.820	
	- Wearing gloves.	0.747	
	- Wearing helmet.	0.716	
Post- application (P. application)	- Changing the suit after pesticides application.	0.811	CR= 0.831; AVE= 0.650; Cronbach's alpha= 0.782
	- Washing hands, face, and body after pesticides application.	0.798	
	- Disinfecting protective equipment after pesticides application.	0.724	
	- Disposing cans and pesticides residues safety (burying, burning, etc.).	0.715	

Table 2. Levels of SB among Farmers.

Range of SB	0.0- 0.2	0.21- 0.4	0.41- 0.6	0.61- 0.8	0.81- 1.0
Categories (levels)	Completely unsafe behavior	Relatively unsafe behavior	Moderately safe behavior	Relatively safe behavior	Completely safe behavior

Resource: Damalas and Abdollahzadeh (2016); Ko (2005)

Data analysis

Structural equation modeling (SEM) was used to determine the effectiveness of research variables on farmers' safety behavior (SB), considering latent and mediating variables. First, measurement models were validated (Table 1), then all three models were fitted to test the hypotheses. Predictive power of the models was evaluated and compared. Goodness-of-fit was assessed using indices: χ^2/df, p-value, GFI, AGFI, CFI, IFI, and RMSEA, with desirable thresholds as per Hair et al. (2010) and Rezaei et al. (2020). The Chi-square difference test ($\Delta\chi^2$) was also applied for model comparison alongside fit indices (Chen, 2016; Rezaei et al., 2020). SB was defined across four stages: purchase and storage, preparation, application, and post-application of pesticides. To measure SB level, values were calculated using a formula, yielding scores between 0 and 1, which were then categorized into five levels (Damalas and Abdollahzadeh, 2016; Sharifzadeh et al., 2018; Singh and Hiremath, 2010).

$$\text{SB levels} = \frac{(SB_K - SB_{min})}{(SB_{max} - SB_{min})}$$

In which:

SB_K: Overall SB of each tomato farmer (Ki).

SB_{min}: Minimum overall SB among tomato farmers.

SB_{max}**:** Maximum overall SB among tomato farmers.

The values calculated by the formula were categorized in five different levels as defined in Table 2 (Damalas and Abdollahzadeh, 2016; Ko, 2005).

RESULTS AND DISCUSSION

Table 3 summarizes key demographic characteristics of the respondents. The obtained values are: age, 43 years; education level, 17 years; household size, 8 individuals; yield, 29.00 t/ha; agricultural experience, 29 years; average annual agricultural income, 3,960 million IRR; average annual off-farm income, 400 million IRR; farm size, 17.0 hectares; and number of agricultural machinery owned, 6. According to Table 4, the most important SB items in the stages of pesticide purchase and storage, preparation, application, and post-application were "determining the appropriate pesticide type for the pest and disease and checking its production and expiry dates", "preparing pesticides outside the house", "using boots", and "changing the suit after pesticide application", respectively. The lowest priorities were "purchasing from reliable pesticide stores", "reading instructions on the pesticide label carefully before use", "wearing a helmet", and "disposing of cans and pesticide residues safely (burying, burning, etc.)", respectively. These findings seem to result from inadequate information sources on pesticide use, high costs of safety equipment and appropriate sprayers, and low farmer knowledge. Furthermore, government incentive policies and intergovernmental organizations promoting increased production have led to greater use of artificial and chemical inputs by farmers (in agreement with Rezaei et al., 2020). Based on the findings in Figure 3, farmer groups were classified by levels of SB in using chemical pesticides as follows: completely unsafe behavior (20.65%); relatively unsafe (31.94%); moderately safe behavior (23.23%); relatively safe behavior (17.42%); and completely safe

Table 3. The Summary of Some Demographic Characteristics.

Variables	Mean	S.D.	Min.	Max.
Age (year)	45.92	10.768	28	71
Educational level (year)	11.06	3.968	0	17
Agricultural experience (year)	11.59	7.472	2	31
Household size (person)	4.21	1.451	2	10
Farm size (ha)	3.15	3.579	1.0	18
Tomato yield (t/ha)	39.43	4.171	22	51
Annual farm income (million IRR[1])	1878.61	807.31	840.00	4800
Annual off-farm income (million IRR)	110.53	98.474	0	400
Ownership of agricultural machinery (no.)	1.14	1.296	0	6

[*] 1. 1 US dollar≈450,000 Iranian Rials (IRR)

Table 4. Ranking of Stages of Farmers' SB and Their Information Sources in Using Pesticides.

Stages of SB	Ranking of items of each stage			Rank
	Items	Mean	S.D.	
Purchase and storage	- Determining appropriate pesticide type for the pest and disease and checking its production and expiring dates.	2.95	1.00	1
	- Storing out of the reach of children and animals.	2.73	1.40	2
	- Attending the recommendations of agricultural experts in selecting chemical pesticides	2.62	1.48	3
	- Selecting and purchasing pesticides with lower risk hazards and more environmentally friendly.	2.57	1.34	4
	- Acquiring adequate knowledge of how to store pesticides correctly.	2.45	1.16	5
	- Purchasing from reliable pesticides stores.	2.39	1.39	6
Preparation	- Preparing pesticides outside the house.	3.10	1.11	1
	- Using protective equipment (gloves, mask, etc.) when solving or mixing pesticides.	3.03	1.19	2
	- Attending the quality of soluble (water) or mixture in pesticide preparation.	3.01	1.14	3
	- Learning how to prepare a mixture or solution of pesticide correctly.	3.00	1.21	4
	- Reading instructions on the label of pesticides before use carefully	2.90	1.09	5
Application	- Using boots.	2.55	1.21	1
	- Avoiding pesticide spraying at adverse weather or in the opposite direction of wind.	2.51	1.21	2
	- Using mask or a piece of cloth.	2.50	1.07	3
	- Wearing safety glasses.	2.45	1.21	4
	- Wearing protective gown.	2.44	1.13	5
	- Wearing gloves.	2.03	1.02	6
	- Wearing helmet.	1.85	1.12	7
Post-application	- Changing the suit after pesticides application.	2.39	1.11	1
	- Washing hands, face, and body after pesticides application.	2.34	0.94	2
	- Announcing the application of pesticides on farm and not letting others to enter the farm.	2.20	1.14	3
	- Disinfecting protective equipment after pesticides application.	2.14	0.95	4
	- Disposing cans and pesticides residues safety (burying, burning, etc.).	1.69	1.09	5

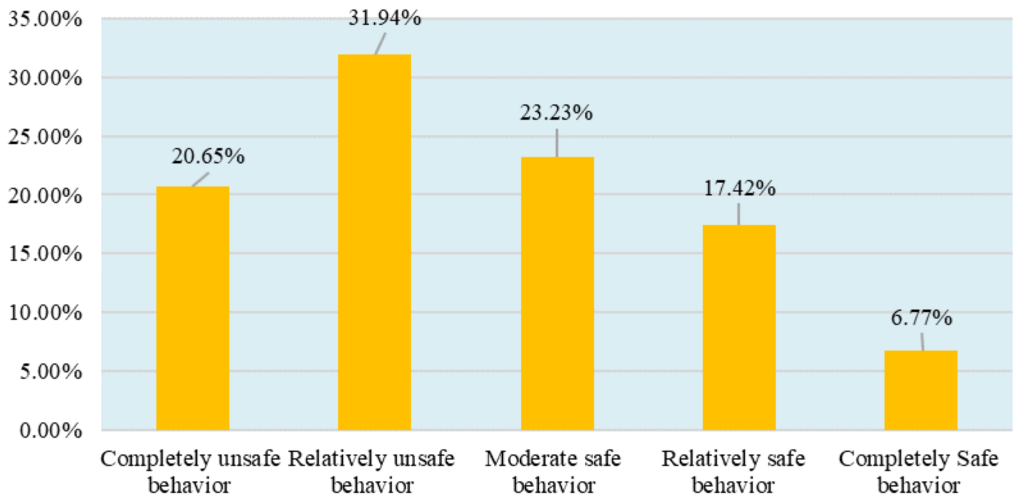

Figure 2. SB Levels among Farmers.

Table 5. Results of Chi-Square Difference Tests and Fit Indices for Models.

Models	X^2/df	Δ X^2(df)	P	GFI	AGFI	CFI	IFI	RMSEA
TPB	3.209	-	0.002	0.901	0.900	0.909	0.902	0.079
HBM	5.643	-	0.073	0.861	0.901	0.872	0.886	0.120
Integrated model	2.440	-	0.000	0.905	0.903	0.915	0.906	0.068
Criteria for goodness-of-fit	≤5	-	≥0.05	≥0.90	>0.90	≥0.90	≥0.90	≤0.08
TPB vs. HBM	-	299.235 (21)	0.024					
TPB vs. Integrated model	-	242.115 (114)	0.195					
HBM vs. Integrated model	-	57.120 (93)	0.001					

Note: GFI = Goodness of Fit Index; AGFI; Adjusted GFI; CFI = Comparative Fit Index; IFI= Incremental Fit Index; RMSEA = Root Mean Square Error of Approximation

behavior (6.77%). The largest group comprised farmers with relatively unsafe behavior (in agreement with Jallow et al., 2017), while those exhibiting completely safe behavior formed the smallest group.

The fit index results for each model are presented in Table 5. The X^2/df values for the integrated model (2.440) and TPB model (2.935) were below 5, while for the HBM model (5.643) it exceeded 5. Thus, the HBM showed poor fit, whereas the integrated and TPB models demonstrated acceptable fit. Additionally, Figures 3 and 4 show that the R^2 for SB in the integrated model (0.632) was higher than in the HBM (0.407) and TPB (0.523) models. Chi-square comparisons in Table 5 revealed a significant difference in explanatory power between HBM and both TPB and the integrated model, but no significant difference between the integrated model and TPB. Overall, the integrated model has greater predictive power for SB and is the more optimal model.

The structural relationships in the conceptual model (Figure 4) show that attitude (ß= 0.283), perceived severity (ß= 0.410), self-efficacy (ß= 0.242), perceived behavioral control (ß= 0.244), and cues to action (ß= 0.452) have positive and significant effects on intention. Perceived barriers (ß= -0.342) had a significant negative effect on intention (consistent with Sharifzadeh et al., 2019; contrary to Yuen et al., 2020; Wang et al., 2019; Moradhaseli et al., 2019), while subjective norms (ß= 0.373) had a significant positive effect (contrary to Liu et al., 2020; Rezaei et al., 2020). These findings support hypotheses H2, H3, H4, H6, H7, H8, and H9 in the integrated model.

Additionally, consistent with Rezaei et al. (2020), Yuen et al. (2020), and Wang et al. (2019), self-efficacy positively affected both intention (ß= 0.243) and SB (ß= 0.354), and intention had a strong positive effect on SB (ß= 0.672). However, perceived benefits (ß= 0.034) and perceived susceptibility (ß= 0.083) had non-significant effects on intention, leading to rejection of hypotheses H1 and H5. Hypotheses H10 and H11 were supported.

Most farmers in Iran, including this study's participants (mean farm size: 3.15 ha), have small, scattered farms and limited financial capacity (supported by Rezaei et al., 2020; Sookhtanlou et al., 2022). Thus, the cost of safety equipment relative to income is not a strong motivator, which explains why perceived benefits were not a significant factor.

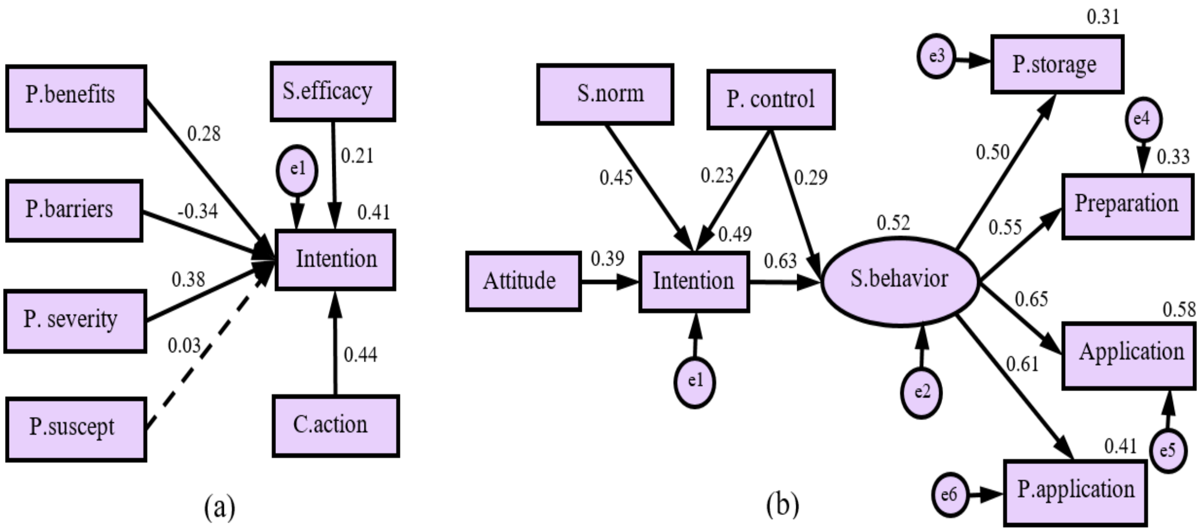

Figure 3. Standardized Coefficients for HBM (**a**) and TPB (**b**) Models

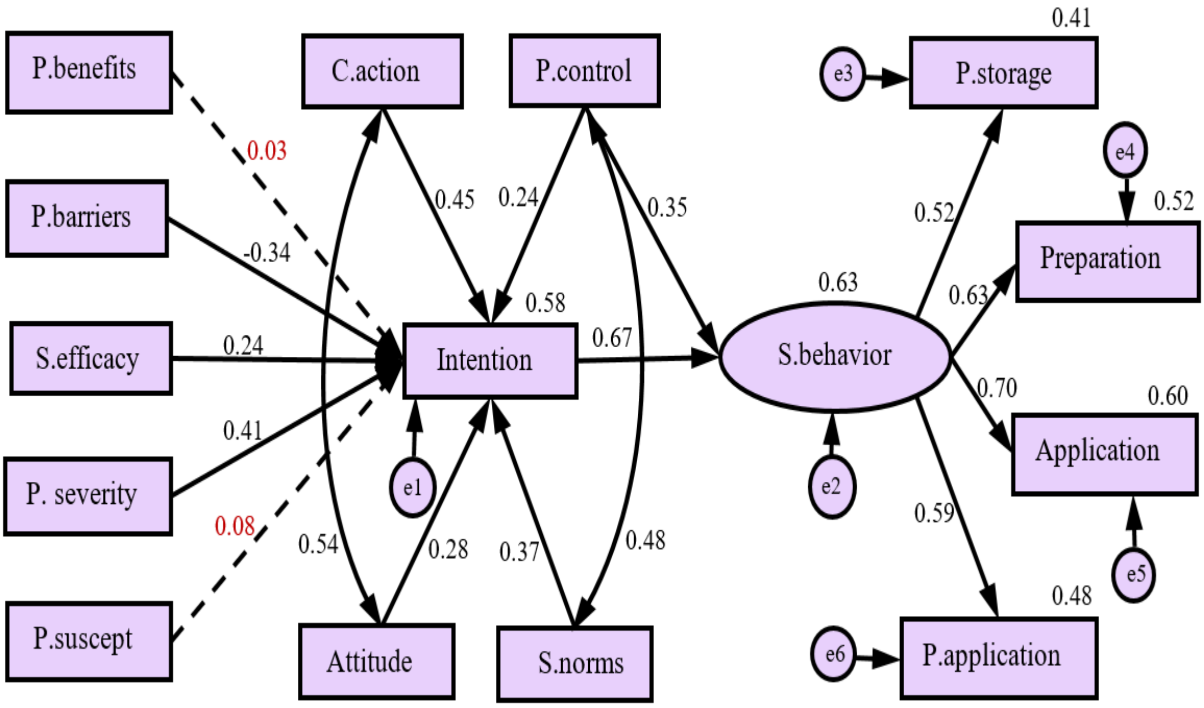

Figure 4. Standardized Coefficients in the Integrated Model.

Among the main 10 paths of the integrated model and according to the results from the overall direct and indirect effects (Table 6), those paths highly explaining overall SB of farmers are related to the variables of intention (intention→SB; ß= 0.672), perceived behavioral control (perceived behavioral control→ SB; ß= 0.516) and cues to action (cues to action→ intention→SB; ß= 0.304), respectively. This finding was consistent with the results of Kahramanoglu (2020), Damalas and Koutroubas (2018), and Mazloomy Mahmoodabad et al. (2019).

According to Figure 4, in the integrated model, the stage of chemical pesticide application had the highest explanatory power for SB, with $R^2 = 0.604$, explaining 63 percent of the variance in effective variables. The R^2 values for purchase and storage, preparation, and post-application stages were 0.411, 0.523, and 0.483, respectively. Thus, the application stage has the greatest explanatory ability among the SB stages.

CONCLUSIONS

The present study used a comprehensive integrated model to evaluate tomato farmers' SB across four stages—purchase and storage, preparation, application, and post-application of pesticides—achieving higher explanatory power than common models. It also identified the pesticide application stage as having the highest explanatory power for research variables. Results showed that tomato farmers have relatively low SB levels, placing them at ongoing health risk. Thus, reducing chemical pesticide use should be a priority for regional agricultural planners.

Table 6. Significant Coefficients of Path Analysis, Relating to the Latent Structures in the Integrated Model.

Main paths of model	Direct effects	Indirect paths	Indirect effects	Overall effects	*p*-value
1. Perceived benefits→ SB	0	Perceived benefits→ Intention → SB	0.023	0.023	0.473
2. Perceived barriers → SB	0	Perceived barriers→ Intention → SB	-0.230	-0.230	0.012
3. Self-efficacy→ SB	0	Self-efficacy→ Intention→ SB	0.163	0.163	0.024
4. Perceived severity→ SB	0	Perceived severity→Intention → SB	0.276	0.276	0.005
5. Perceived susceptibility → SB	0	Perceived susceptibility→ Intention → SB	0.056	0.056	0.403
6. Cues to action→SB	0	Cues to action→ Intention→SB	0.304	0.304	0.000
7. Attitude → SB	0	Attitude →Intention →SB	0.190	0.190	0.027
8. Subjective norms→SB	0	Subjective norms→ Intention→ SB	0.251	0.251	0.009
9. Perceived behavioral control →SB	0.352	Perceived behavioral control → Intention→ SB	0.164	0.516	0.000
10. Intention →SB	0.672	-	0	0.672	0.000

Key predictors of farmers' SB were intention, perceived behavioral control, and cues to action. Raising farmers' awareness about the negative effects of unsafe pesticide use via visual and audio media can enhance their intention and perceived behavioral control. Cues to action likely work synergistically with perceived severity, as public and local media, bulletins, brochures, and training programs (cues to action) improve safe pesticide behaviors. Enhancing perceived behavioral control and cues to action ultimately fosters stronger intention and positive SB changes. The integrated model demonstrated higher explanatory power compared to HBM and TPB alone, with the pesticide application stage showing the greatest explanatory ability. This model offers a robust alternative for studying farmers' SB, with broader generalizability than extended versions of individual models, which tend to be context-specific. Limitations include the focus on tomato farmers, limiting generalizability to other crops with different chemical inputs and production conditions, and the predominance of smallholder farmers, which may not align with studies involving medium or large-scale farmers. Future research should expand the integrated model to diverse crops and farmer groups to improve its internal consistency and applicability.

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CONFLICTS OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

AUTHORS' CONTRIBUTIONS

Mojtaba Sookhtanlou (First Author and Supervisor) was responsible for overseeing the research design, as well as the conceptualization, methodology, analysis, and interpretation of the data. Zahra Khoshnodifar administered the research process, conducted the literature review, and coordinated data collection efforts. Additionally, all authors reviewed and approved the final version of the manuscript.

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