

The Effects of Farmers' Pesticide Safety Information Behavior on Pesticide Safety Practice: The Mediating Role of Safety Education

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Abstract: This study examined the structural relationships among Pesticide Safety Information Behavior (PSIB), Pesticide Safety Education (PSE), and Pesticide Safety Practices (PSP) among farmers. A questionnaire survey was conducted with 184 farmers in Jeonbuk State, Republic of Korea. The collected data were analyzed using SPSS Statistics 29.0 and Amos 26.0 through exploratory factor analysis (EFA), confirmatory factor analysis (CFA), structural equation modeling (SEM), and bootstrapping analysis to examine the mediating effects. The results showed that Information Utilization and Information Awareness had significant positive effects on Pesticide Safety Education. In addition, Pesticide Safety Education had a significant positive effect on Pesticide Safety Practices, while Information Awareness also exerted a direct positive effect on Pesticide Safety Practices. In contrast, Information Seeking had no statistically significant effect on either Pesticide Safety Education or Pesticide Safety Practices. The bootstrapping analysis further confirmed that Pesticide Safety Education significantly mediated the relationships between Information Utilization and Pesticide Safety Practices, as well as between Information Awareness and Pesticide Safety Practices. These findings indicate that farmers' pesticide safety practices are promoted not merely by seeking information but by effectively utilizing pesticide safety information and strengthening their awareness through Pesticide Safety Education. The findings suggest that improving farmers' pesticide safety practices requires a shift from one-time educational programs toward participatory and customized safety education designed to strengthen farmers' information utilization capabilities. In particular, developing field-oriented educational content tailored to the needs of older farmers and specific crop types, together with practical support integrated with pesticide safety information systems, will be essential for promoting sustainable pesticide safety practices.

Keywords: Pesticide safety education, Pesticide safety information behavior, Pesticide safety practice, Structural equation modeling

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Introduction

Pesticides refer to a broad range of chemical agents used to prevent, control, or eliminate fungi, insects, mites, nematodes, viruses, weeds, and other pests and diseases that adversely affect crop production [1]. As indispensable agricultural inputs, pesticides play a vital role in improving crop productivity and ensuring stable agricultural production. However, because the inherent toxicity of pesticides and other chemical substances cannot be completely eliminated, the potential risks to

human health and the environment can be substantially reduced through proper handling and strict compliance with established safety guidelines [2]. Therefore, effective pesticide management and adherence to recommended safety practices are essential for minimizing the adverse effects associated with pesticide use.

In South Korea, pesticide production reached 20,746 tons of active ingredients in 2022, comprising fungicides (36.3%), insecticides (25.3%), herbicides (30.3%), plant growth regulators (2.4%), and other pesticide products (5.6%). Pesticide application intensity was 19.5 kg/ha in 2015, 17.1 kg/ha in 2020, and 19.9 kg/ha in 2022, indicating year-to-year fluctuations rather than a consistent increasing or decreasing trend. These fluctuations are attributable not only to climatic conditions and crop growth characteristics but also to government policies designed to ensure stable agricultural production and food security. Consequently, although the level of pesticide use varies over time, pesticides continue to play an indispensable role in maintaining agricultural productivity.

Meanwhile, farmers are exposed to a wide range of occupational hazards, including physically demanding agricultural work, hazardous chemicals such as pesticides, biological agents in livestock facilities and greenhouses, heat stress and dust generated during outdoor work, and accidents involving agricultural machinery. Pesticide-related accidents continue to occur every year and remain a major occupational health concern for farmers. In 2023, a total of 337 pesticide poisoning cases were reported, including 225 cases associated with pesticide spraying, 55 cases resulting from accidental ingestion after being mistaken for beverages, 31 cases caused by residual pesticide exposure, and 26 cases related to pesticide handling and other causes. The incidence of pesticide poisoning was highest during the summer months, with 73 cases (21.7%) in July, 65 cases (19.3%) in June, and 54 cases (16.0%) in August. Furthermore, 257 cases (76.3%) involved individuals aged 60 years or older. These findings indicate that pesticide poisoning incidents are concentrated among older farmers and during periods of intensive pesticide application. Therefore, strengthening farmers' awareness of pesticide safety and promoting safe pesticide use practices through targeted education and effective safety management programs are essential for reducing pesticide-related health risks.

To strengthen food safety and ensure the safe distribution of agricultural products in both domestic and international markets, the Korean government has continuously reinforced its pesticide residue management system by establishing crop-specific maximum residue limits (MRLs). As part of these efforts, the Positive List System (PLS) was fully implemented in January 2019. Under the PLS, a uniform maximum residue limit of 0.01 ppm is applied to pesticides for which no crop-specific MRL has been established, thereby enhancing the safety management of agricultural products. Along with the implementation of the PLS, the government has strengthened pesticide safety education based on the legal framework established under Article 23, Paragraphs 2 and 3 of the Pesticide Control Act. The primary objective of this education is to improve farmers' compliance with pesticide regulations by enhancing their knowledge of safe pesticide use and handling practices. Farmers are required to complete this training at least once each year, covering key topics such as pesticide-related laws and regulations, pesticide registration and distribution systems, safe pesticide application practices, and agricultural product safety inspection procedures. Through these educational efforts, the government seeks to promote the safe and responsible use of pesticides while reducing pesticide-related risks to both human health and the environment.

These institutional measures are expected to positively influence farmers' pesticide use practices and information awareness. In particular, compliance with pesticide use record-keeping requirements and participation in mandatory safety education provide a solid foundation for the effective implementation of the PLS. Previous studies have also suggested that expanding pesticide safety education and promotional programs for farmers can further improve compliance with pesticide regulations and encourage safer pesticide use practices [3].

International research has consistently emphasized the importance of pesticide safety behavior among farmers. Previous studies have examined a wide range of topics, including pesticide safety practices among Greek farmers [4], the effects of farmers' pesticide information awareness on safe pesticide handling behavior [5], differences in pesticide safety practices according to participation in pesticide safety education [6], and the determinants of farmers' pesticide use behavior [7]. These findings highlight the critical role of information awareness and education in promoting appropriate pesticide use and reducing pesticide-related health risks.

Domestic studies have investigated various aspects of pesticide safety, including compliance with pesticide registration standards [8], the analysis and prevention of pesticide poisoning fatalities [2], farmers' awareness and implementation of pesticide safety practices [9], awareness of non-compliant pesticide residues [10], and farmers' pesticide safety behaviors [11]. These studies have provided valuable insights into farmers' information awareness, pesticide poisoning incidents, and factors influencing safe pesticide use.

However, previous domestic research has focused primarily on farmers' information awareness, safety practices, and pesticide poisoning incidents, whereas relatively little attention has been paid to the role and effectiveness of pesticide safety education. Moreover, few studies have adopted a comprehensive framework to examine the structural relationships among pesticide safety information behavior, perceptions of pesticide safety education, and pesticide safety practices. Despite the nationwide implementation of the PLS, empirical research investigating these relationships from a structural perspective remains limited.

This study therefore aims to examine the structural relationships among farmers' pesticide safety information behavior, perceptions of pesticide safety education, and pesticide safety practices in the post-PLS era. By applying structural equation modeling (SEM), this study provides empirical evidence to enhance farmers' pesticide information awareness and practices, thereby offering practical implications for the development of more effective pesticide safety education and management strategies.

Results and Discussion

Characteristics of the Survey Participants

The demographic characteristics of the survey participants are presented in Table 1. Of the 184 respondents, 137 (74.5%) were male and 47 (25.5%) were female. The largest age group was participants in their 50s (27.2%), followed by those in their 60s (26.6%), 40s (17.9%), and 30 years or younger (15.2%). Regarding educational attainment, 101 participants (54.9%) had completed high school or less, whereas 83 (45.1%) had obtained a college or university degree. With respect to farming experience, 73 participants (39.7%) had farmed for 10 years or less, followed by 39 (21.2%) with 11–20 years, 28 (15.2%) with 21–30 years, and 44 (23.9%) with 31 years or more of farming experience. During the previous three years, 20 participants (10.9%) reported having experienced pesticide poisoning. Regarding participation in pesticide safety education, 30 participants (16.3%) had not attended any training during the previous year, 85 (46.2%) had participated once, 49 (26.6%) had attended twice, and 20 (10.9%) had participated three or more times. Agricultural cooperatives were the primary source of pesticide purchases for 126 participants (68.5%), followed by pesticide retailers (55 participants, 29.9%). The main sources of pesticide-related information were public institutions (72 participants, 39.1%) and pesticide retailers (71 participants, 38.6%), whereas only 7 participants (3.8%) identified neighboring farmers as their primary information source.

Reliability and Validity of the Measurement Model

An exploratory factor analysis (EFA) was conducted to examine the construct validity of the measurement scales. Factors were extracted using principal component analysis (PCA) with Varimax orthogonal rotation. Following the recommendations of previous studies [12], only items with factor loadings of 0.50 or higher were retained, and factors with eigenvalues greater than 1.0 were extracted.

As presented in Table 2, the Kaiser–Meyer–Olkin (KMO) measures of sampling adequacy were 0.885 for pesticide safety information behavior (information seeking, information utilization, and information awareness), 0.850 for pesticide safety education, and 0.862 for pesticide safety practices, indicating that the data were suitable for factor analysis. Internal consistency reliability was assessed using Cronbach's α , and all constructs exceeded the recommended threshold of 0.70, demonstrating satisfactory reliability.

A confirmatory factor analysis (CFA) was subsequently performed to evaluate the measurement model. The relationships between the latent constructs and their observed indicators were estimated using the maximum likelihood (ML) estimation method

Table 1. General Characteristics of the Subjects

Division		N	%	Division		N	%
Gender	Male	137	74.5	Number of Safety Training Sessions Attended per Year	None	30	16.3
	Female	47	25.5		1 time	85	46.2
Age	≤39 years	28	15.2		2 times	49	26.6
	40-49 years	33	17.9		3 times or more	20	10.9
	50-59 years	50	27.2	Main Source of Pesticide Purchase	Agricultural Cooperative (NongHyup)	126	68.5
	60-69 years	49	26.6		Pesticide Retailer	55	29.9
	≥70 years	24	13.1		Others	3	1.6
Education	≤High school	101	54.9	Source of Pesticide Information	Government or Agricultural Agencies	72	39.1
	≥Bachelor's degree	83	45.1		Pesticide Retailers	71	38.6
Farming Experience	≤10 years	73	39.7		Internet Search	17	9.2
	11-20 years	39	21.2		Agricultural Training Programs	16	8.7
	21-30 years	28	15.2		Fellow Farmers	7	3.8
	≥31 years	44	23.9		Others	1	0.6
Pesticide Poisoning (Past 3 years)	Yes	20	10.9	Total		184	100.0
	No	164	89.1				

Table 2. Results of Validity and Reliability Analysis of Measurement Tools

Research Construct	Item	Factor Loading*	Communality	Eigenvalue	Variance Explained (%)	KMO Measure**	Cronbach's α
Pesticide Safety Information Behavior (PSIB)	Information Seeking (IS)	IS1	0.853	0.820	3.623	30.193	0.874
		IS2	0.757	0.800			
		IS3	0.718	0.773			
	Information Utilization (IU)	IU1	0.771	0.729	3.261	27.179	0.907
		IU2	0.831	0.814			
		IU3	0.745	0.643			
		IU4	0.824	0.764			
		IU5	0.698	0.739			
	Information Awareness (IA)	IA1	0.795	0.829	2.620	21.830	0.927
		IA2	0.801	0.850			
		IA3	0.823	0.830			
		IA4	0.880	0.913			
Pesticide Safety Education (PSE)	PSE1	0.761	0.580	3.840	76.806	0.850	0.920
	PSE2	0.907	0.823				
	PSE3	0.923	0.852				
	PSE4	0.910	0.828				
	PSE6	0.870	0.758				
Pesticide Safety Practices (PSP)	PSP1	0.792	0.627	4.011	66.858	0.862	0.900
	PSP2	0.843	0.710				
	PSP4	0.839	0.704				
	PSP7	0.789	0.623				
	PSP8	0.834	0.696				
	PSP9	0.807	0.652				

*Items PSE5, PSE7, PSP3, PSP5, and PSP6, which exhibited factor loadings below 0.50, were excluded from the analysis. Furthermore, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was employed to evaluate the suitability of the data for factor analysis, with a KMO value of 0.70 or higher indicating acceptable sampling adequacy.

Table 3. Confirmatory Factor Analysis (CFA) Results^a

Research Construct		Item	Factor Loading	S.E.	C.R*	AVE**	CR***
Pesticide Safety Information Behavior (PSIB)	Information Seeking (IS)	IS1	0.794	0.415	-	0.675	0.862
		IS2	0.850	0.310	10.321		
		IS3	0.855	0.277	12.727		
	Information Utilization (IU)	IU1	0.806	0.383	-	0.611	0.886
		IU2	0.701	0.451	10.265		
		IU3	0.823	0.280	12.686		
		IU4	0.827	0.430	12.779		
		IU5	0.878	0.541	13.877		
	Information Awareness (IA)	IA1	0.915	0.157	-	0.770	0.930
		IA2	0.894	0.168	18.860		
		IA3	0.723	0.430	12.132		
		IA4	0.905	0.133	19.399		
Pesticide Safety Education (PSE)	PSE1	0.717	0.602	-	0.692	0.917	
	PSE2	0.837	0.279	11.123			
	PSE3	0.930	0.125	12.340			
	PSE4	0.909	0.183	12.086			
	PSE6	0.790	0.385	10.475			
Pesticide Safety Practices (PSP)	PSP1	0.822	0.267	-	0.614	0.905	
	PSP2	0.835	0.264	13.242			
	PSP4	0.768	0.359	11.796			
	PSP7	0.777	0.366	9.824			
	PSP8	0.751	0.495	11.447			
	PSP9	0.710	0.535	10.627			

^aModel Fit: $\chi^2=572.555$ ($p<0.001$), $df=217$, $\chi^2/df=2.639$, TLI=0.889, NFI=0.856, CFI=0.905, RMSEA=0.095.

*C.R.=Critical Ratio, **AVE(Average Variance Extracted) ≥ 0.5 , ***CR(Construct Reliability) ≥ 0.7 .

[13]. The CFA results are summarized in Table 3.

The measurement model demonstrated an acceptable level of fit, with TLI=0.889, NFI=0.856, CFI=0.905, and RMSEA=0.095. Convergent validity was assessed using average variance extracted (AVE) and construct reliability (CR). As recommended in previous studies [12,14], convergent validity is considered acceptable when AVE exceeds 0.50 and CR exceeds 0.70. All constructs satisfied these criteria, confirming adequate convergent validity.

Discriminant validity was evaluated using the Fornell–Larcker criterion, which requires the AVE of each construct to exceed the squared correlations between that construct and all other constructs [14]. As shown in Table 4, all constructs met this criterion, thereby confirming satisfactory discriminant validity.

Results of Hypothesis Testing

The results of the SEM analysis are presented in Table 5. The proposed structural model demonstrated an acceptable fit to the data, with goodness-of-fit indices of $\chi^2/df=2.520$, TLI=0.895, NFI=0.862, CFI=0.911, and RMSEA=0.091. Although the RMSEA value was slightly higher than the recommended criterion, the overall model fit was considered acceptable because the remaining fit indices met or were close to the recommended thresholds.

The results showed that Information Utilization ($\beta=0.338$, $p<.01$) and Information Awareness ($\beta=0.314$, $p<.01$) had significant positive effects on Pesticide Safety Education, whereas Information Seeking ($\beta=0.163$, $p>.05$) did not have a statistically significant effect.

Table 4. Analysis of Discriminant Validity of Research Constructs

Factor		1	2	3	4	5
Pesticide Safety Information Behavior	Information Seeking	0.675				
	Information Utilization	0.634	0.611			
	Information Awareness	0.572	0.442	0.770		
Pesticide Safety Education		0.420	0.452	0.426	0.692	
Pesticide SafetyPractices		0.496	0.382	0.581	0.581	0.614

*The diagonal elements represent the Average Variance Extracted (AVE) for each construct, whereas the off-diagonal elements represent the squared correlations between constructs (γ^2).

Table 5. Results of Hypothesis Testing^a

Hypothesis	Path	Path Coefficient (β)	S.E	C.R.	Hypothesis Result
H1a	Information Seeking $\rightarrow$ Safety Education	0.163	0.133	1.189	Not Supported
H1b	Information Utilization $\rightarrow$ Safety Education	0.338**	0.098	2.988	Supported
H1c	Information Awareness $\rightarrow$ Safety Education	0.314**	0.091	3.132	Supported
H2	Safety Education $\rightarrow$ Safety Practices	0.456***	0.078	5.440	Supported
H3a	Information Seeking $\rightarrow$ Safety Practices	0.182	0.102	1.605	Not Supported
H3b	Information Utilization $\rightarrow$ Safety Practices	-0.091	0.076	-0.965	Not Supported
H3c	Information Awareness $\rightarrow$ Safety Practices	0.386***	0.073	4.407	Supported

^aModel Fit: $\chi^2=539.249$ ($p<0.001$), $df=214$, $\chi^2/df=2.520$, $TLI=0.895$, $NFI=0.862$, $CFI=0.911$, $RMSEA=0.091$.

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Pesticide Safety Education had a significant positive effect on Pesticide Safety Practices ($\beta=0.456$, $p<0.001$). Regarding the direct effects of Pesticide Safety Information Behavior on Pesticide Safety Practices, Information Awareness had a significant positive effect ($\beta=0.386$, $p<0.001$), whereas Information Seeking ($\beta=0.182$, $p>0.05$) and Information Utilization ($\beta=-0.091$, $p>0.05$) did not show statistically significant effects.

The results of the mediation analysis are presented in Table 6. The mediating role of Pesticide Safety Education was examined using the bootstrapping procedure. A mediating effect was considered statistically significant when the 95% bootstrap confidence interval (CI) did not include zero [15]. The results indicated that Pesticide Safety Education significantly mediated the relationship between Information Utilization and Pesticide Safety Practices ($\beta=0.154$, 95% CI = [0.009, 0.392]). Likewise, Pesticide Safety Education significantly mediated the relationship between Information Awareness and Pesticide Safety Practices ($\beta=0.143$, 95% CI = [0.044, 0.276]). However, the indirect effect of Information Seeking on Pesticide Safety Practices through Pesticide Safety Education was not statistically significant.

Conclusions

This study examined the structural relationships among Pesticide Safety Information Behavior (PSIB), Pesticide Safety Education (PSE), and Pesticide Safety Practices (PSP) among farmers using SEM. The findings provide empirical evidence that farmers' pesticide safety practices are directly influenced by pesticide safety information behavior and indirectly influenced through the mediating role of pesticide safety education.

The results showed that Information Awareness had a significant positive direct effect on Pesticide Safety Practices. In addition, both Information Utilization and Information Awareness significantly enhanced farmers' perceptions of Pesticide Safety Education, which subsequently promoted Pesticide Safety Practices. The mediation analysis further confirmed that Pesticide Safety Education

Table 6. Results of Bootstrapping Mediation Effect Verification

Mediation Path				Standardized Coefficient (β)	S.E	Boot. 95% Cla		
						LLCI	ULCI	
Information Seeking	→	Safety Education	→	Safety Practices	0.074	0.141	-0.095	0.306
Information Utilization	→	Safety Education	→	Safety Practices	0.154	0.116	0.009	0.392
Information Awareness	→	Safety Education	→	Safey Practices	0.143	0.074	0.044	0.276

^aCI=Confidence interval, LLCI=Lower limit of CI, ULCI=Upper limit of CI.

* $p < .05$, ** $p < .01$, *** $p < .001$

significantly mediated the relationships between Information Utilization and Pesticide Safety Practices, as well as between Information Awareness and Pesticide Safety Practices. These findings are consistent with previous studies reporting that pesticide safety education enhances farmers' pesticide-related knowledge, risk control beliefs, and safety behaviors [6,8]. They also support earlier research suggesting that pesticide safety practices are influenced not only by knowledge but also by behavioral factors such as attitudes, subjective norms, and perceived behavioral control [5].

The findings indicate that farmers' pesticide safety practices depend not only on access to pesticide-related information but also on their ability to understand, evaluate, and effectively utilize that information. More importantly, the significant mediating role of Pesticide Safety Education demonstrates that education is a key mechanism for translating pesticide safety information into safe pesticide use practices. Therefore, strengthening farmers' information utilization capabilities through continuous, practice-oriented, and participatory education should be considered a priority for improving pesticide safety practices.

From a policy perspective, pesticide safety education should move beyond conventional lecture-based approaches toward participatory and customized educational programs tailored to farmers' educational needs, crop characteristics, and regional farming conditions [7]. In particular, educational content should be simplified and adapted for older farmers, while continuous refresher training, field-based practical education, and the integration of digital pesticide safety information systems should be expanded to promote the sustained adoption of safe pesticide use practices.

Materials and Methods

Research Model and Hypothesis

The proposed research model, presented in Fig. 1, was developed to examine the structural relationships among Pesticide Safety Information Behavior, Pesticide Safety Education, and Pesticide Safety Practices. The model is grounded in the information-processing perspective, which suggests that individuals acquire, interpret, and utilize information before translating it into behavioral responses. Applied to the present study, farmers' pesticide safety practices are expected to be influenced by their information-seeking activities, their ability to utilize pesticide-related information, and their awareness of pesticide safety.

In this study, Pesticide Safety Information Behavior is conceptualized as a multidimensional construct comprising Information Seeking, Information Utilization, and Information Awareness, whereas Pesticide Safety Education represents farmers' perceptions of the usefulness, effectiveness, and educational value of pesticide safety training programs. Based on this framework, it is assumed that farmers with higher levels of pesticide safety information behavior are more likely to recognize the value of pesticide safety education, which subsequently enhances their adoption of appropriate pesticide safety practices, including compliance with safety guidelines, the use of personal protective equipment, and adherence to recommended pesticide application rates.

Accordingly, this study proposes that Pesticide Safety Information Behavior influences Pesticide Safety Practices both directly and indirectly through Pesticide Safety Education. Based on the proposed research model, the following hypotheses were established.

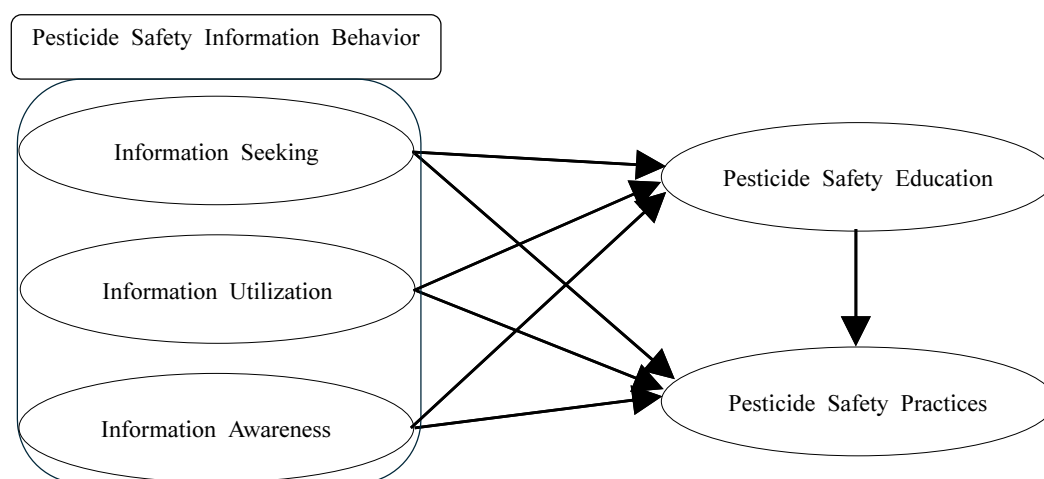


Fig. 1. Research Model.

- H1. Pesticide Safety Information Behavior positively affects Pesticide Safety Education.
 - H1-1. Information Seeking positively affects Pesticide Safety Education.
 - H1-2. Information Utilization positively affects Pesticide Safety Education.
 - H1-3. Information Awareness positively affects Pesticide Safety Education.
- H2. Pesticide Safety Education positively affects Pesticide Safety Practices.
- H3. Pesticide Safety Information Behavior positively affects Pesticide Safety Practices.
 - H3-1. Information Seeking positively affects Pesticide Safety Practices.
 - H3-2. Information Utilization positively affects Pesticide Safety Practices.
 - H3-3. Information Awareness positively affects Pesticide Safety Practices.
- H4. Pesticide Safety Education mediates the relationship between Pesticide Safety Information Behavior and Pesticide Safety Practices.
 - H4-1. Pesticide Safety Education mediates the relationship between Information Seeking and Pesticide Safety Practices.
 - H4-2. Pesticide Safety Education mediates the relationship between Information Utilization and Pesticide Safety Practices.
 - H4-3. Pesticide Safety Education mediates the relationship between Information Awareness and Pesticide Safety Practices.

Operational Definitions of Variables

The operational definitions of the key variables used in this study are presented as follows. Pesticide Safety Information Behavior (PSIB) refers to a series of behaviors through which farmers seek, acquire, understand, and utilize information necessary for the safe use and management of pesticides, while recognizing its potential impacts on human health, the environment, and food safety. In this study, PSIB comprises three dimensions: Information Seeking, Information Utilization, and Information Awareness.

Information Seeking refers to farmers' efforts to search for and obtain pesticide-related information from various sources, including government agencies, agricultural cooperatives, educational programs, and pesticide retailers.

Information Utilization refers to the extent to which farmers understand and apply acquired pesticide safety information to pesticide selection, handling, application, storage, and disposal in their farming practices.

Information Awareness refers to farmers' level of understanding and awareness of the potential impacts of pesticide use on human health, environmental protection, agricultural products, and food safety.

Pesticide Safety Education (PSE) refers to farmers' perceptions of the adequacy, usefulness, effectiveness, and practical value of pesticide safety education programs. It encompasses their evaluation of the educational content, perceived improvement in pesticide

safety knowledge, understanding of the PLS, and the extent to which the education supports the adoption of safe pesticide use practices.

Pesticide Safety Practices (PSP) refer to the degree to which farmers comply with recommended pesticide safety guidelines during pesticide handling and application. These practices include wearing appropriate personal protective equipment, following recommended dilution ratios and application rates, considering weather conditions during pesticide application, safely storing pesticides, and properly disposing of empty pesticide containers.

The questionnaire consisted of measurement items developed based on previous studies [1-3,5,9-11,16-18], as presented in Table 7. The questionnaire included three items measuring Information Seeking, five items measuring Information Utilization, four items measuring Information Awareness, seven items measuring Pesticide Safety Education, and nine items measuring Pesticide Safety Practices, in addition to questions on respondents' demographic characteristics. Except for the demographic variables, all measurement items were assessed using a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Data Collection and Statistical Analysis

A questionnaire survey was conducted from January 16 to February 11, 2025, among farmers in Jeonbuk State, Republic of Korea. The study participants included farmers engaged in rice, vegetable, fruit vegetable, fruit tree, and other crop production. Data were collected through both online (n=84) and offline (n=100) surveys, yielding a total of 184 valid responses for the final analysis.

To test the proposed hypotheses, the data were analyzed in several stages. First, frequency analysis and descriptive statistics

Table 7. Composition of Survey Questions

Factor	Question Item
Pesticide Safety Information Behavior (PSIB)	Information Seeking (IS) (IS1) I know well what I should check first when using pesticides. (IS2) I can distinguish between information about pesticides that I already know and information that requires further investigation. (IS3) I know what information is needed to purchase pesticides.
	Information Utilization (IU) (IU1) I can easily obtain and make use of information sources regarding pesticide sales outlets (IU2) I can easily identify information that is relevant to my needs among pesticide purchasing information. (IU3) I can easily identify exaggerated or false information about pesticides. (IU4) I am familiar with a variety of online sources that provide information on pesticide purchases. (IU5) I am familiar with the Pesticide Safety Information System that provides information on pesticides.
	Information Awareness (IA) (IA1) I have a good understanding of the effects of pesticides on public safety. (IA2) I have a good understanding of the effects of pesticides on agricultural production. (IA3) I have a good understanding of the effects of pesticides on ecosystems. (IA4) I have a good understanding of the effects of pesticides on food safety.
	Pesticide Safety Education (PSE) (PSE1) I regularly participate in pesticide safety education programs (PSE2) Pesticide safety education helps increase my awareness of pesticide safety. (PSE3) Pesticide safety education helps me practice safe pesticide use. (PSE4) Pesticide safety education helps me better understand the Positive List System (PLS).. (PSE5) I have adequate opportunities to receive pesticide safety education.. (PSE6) Pesticide safety education is practically helpful in preventing safety accidents. (PSE7) Pesticide safety education helps me comply with safe pesticide use guidelines in practice.
	Pesticide Safety Practices (PSP) (PSP1) I actively implement the content of pesticide safety education in agricultural practice. (PSP2) I always follow safe pesticide use guidelines when applying pesticides. (PSP3) I follow the instructions for proper pesticide dilution. (PSP4) I comply with exposure safety guidelines, such as wearing a mask and protective clothing, when applying pesticides. (PSP5) I consider weather and wind conditions when applying pesticides. (PSP6) I try to follow the recommended pesticide application rates when applying pesticides. (PSP7) If I suspect pesticide poisoning symptoms after applying pesticides, I intend to visit a hospital or other healthcare facility. (PSP8) I store pesticides in a designated pesticide storage cabinet. (PSP9) I dispose of empty pesticide containers at designated collection sites after using pesticides.
	General Characteristics Gender, Ages, Education, Farming Experience, Pesticide Poisoning(past 3years), Number of Safety Training Sessions Attended per year, Main Source of Pesticide Purchase, Source of Pesticide Information

were performed to examine the demographic characteristics of the respondents. Second, exploratory factor analysis (EFA) and Cronbach's α were conducted to evaluate the construct validity and internal consistency reliability of the measurement scales. Subsequently, confirmatory factor analysis (CFA) was performed to assess the measurement model.

Convergent validity was evaluated using construct reliability (CR) and average variance extracted (AVE), while discriminant validity was assessed using the Fornell–Larcker criterion by comparing the AVE values with the squared inter-construct correlations.

Finally, SEM was employed to examine the structural relationships among Pesticide Safety Information Behavior (PSIB), Pesticide Safety Education (PSE), and Pesticide Safety Practices (PSP). The mediating effect of Pesticide Safety Education was examined using the bootstrapping procedure. All statistical analyses were performed using SPSS Statistics 29.0 and Amos 26.0.

Data Availability: All data are available in the main text or in the Supplementary Information.

Author Contributions: S.-H.M.: Writing - original draft preparation; Data curation; Methodology. D.-H.J.: Data collection; Supervision.

Notes: The authors declare no conflict of interest

Additional Information:

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