SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 11123-11159
Open Access. Online & Print

DOI: 10.5281/zenodo.20125930

DEVELOPMENT AND EFFECTIVENESS OF A COMMUNITY-PARTICIPATORY MODEL FOR PESTICIDE HAZARD PREVENTION AND CONTROL AMONG FARMERS IN THAILAND

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Received: 06/04/2026
Accepted: 29/04/2026

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ABSTRACT

To develop and evaluate a community-participatory model for preventing and controlling pesticide-related hazards among farmers in Suphan Buri Province, and to examine its effects on knowledge, protective behaviors, and biological health indicators. The study employed a participatory action research (PAR) design with a mixed-methods approach conducted in three phases. Phase 1 involved a situational analysis among farmers across five districts (n = 276). Phase 2 focused on developing a community-participatory model using the AIC process, integrated with one cycle of PAOR (Plan–Act–Observe–Reflect). Phase 3 evaluated model effectiveness using a quasi-experimental design comparing an experimental and a control group (n = 30 per group). Participants included stakeholder representatives and farmers aged ≥18 years selected through multistage proportionate random sampling. Data were collected using structured interviews, knowledge and behavior questionnaires, and satisfaction surveys. All instruments demonstrated acceptable validity and reliability (Cronbach's alpha = 0.82). Data were analyzed using descriptive statistics, independent t-tests, and repeated-measures ANOVA Results: At baseline, 77.2% of farmers had high knowledge, whereas preventive behaviors remained moderate. After the 12-week intervention, the experimental group showed significant improvements in knowledge scores (0.63 to 0.84; p < .001) and preventive behavior scores (1.65 to 2.32; p < .001). In addition, the proportion of participants with risky or unsafe cholinesterase levels significantly declined from 46.7% to 13.3% (p = .047). Conclusion: The community participatory model effectively narrowed the knowledge–practice gap and improved both behavioral and physiological outcomes. The model may be adapted for other agricultural settings to strengthen pesticide safety and reduce farmer health risks.

KEYWORDS: Pesticide exposure; Community participation; Participatory action research; Farmer health; Preventive behavior; Cholinesterase; Occupational hazard prevention; Thailand.

1. INTRODUCTION

Thailand remains structurally reliant on the agricultural sector, which continues to absorb a substantial proportion of the national labor force, with approximately 12.43 million workers or nearly one-third of total employment (Forecasting Statistics Division, 2017). Beyond its central role in food production and rural livelihoods, the sector remains a critical driver of export earnings, particularly through rice production, which continues to contribute significantly to national economic stability (National Statistical Office (NSO), 2018). Therefore, safeguarding the health and occupational safety of agricultural workers should be positioned as a national development priority, given its direct implications for labor productivity, economic sustainability, and long-term food system resilience.

At the global level, the United Nations Sustainable Development Goals (SDGs) explicitly address this agenda through Goal 3 (Good Health and Well-being), which seeks to ensure healthy lives and promote well-being for all, and Goal 12 (Responsible Consumption and Production), which emphasizes the environmentally sound management of chemicals and waste throughout their life cycle to minimize adverse impacts on human health and ecosystems (United Nations, 2015) . These international priorities are highly consistent with Thailand's agricultural development context, where efforts to enhance productivity must be carefully balanced with occupational health protection and environmental sustainability.

Despite these policy priorities, Thai farmers continue to face multiple structural challenges, including climate variability, pest outbreaks, and economic uncertainty, all of which reinforce their reliance on pesticides (Amekawa et al., 2022; LaCroix & Visetnoi, 2023; Riwthong et al., 2017). The convenience of purchasing and applying pesticides has become a major driver of widespread use across the cultivation continuum, from seedling preparation to the pre-harvest stage. Rice cultivation, in particular, has been reported to involve a disproportionately high level of pesticide utilization compared with other crop types (Suphim & Songthap, 2024; Toolkiattiwong et al., 2023; Waiyaphat & Kwonpongsagoon, 2025). According to the Office of Agricultural Economics, Thailand imports more than 100,000 tons of pesticides annually, valued at 20–30 billion THB, reflecting the intensive chemical dependency embedded in contemporary agricultural production systems (Office of Agricultural Economics, 2019).

Although pesticides contribute substantially to pest control and agricultural yield improvement, unsafe pesticide-use practices remain highly prevalent among farmers, particularly in low- and middle-income agricultural settings. Common risky behaviors include failure to read product labels, inadequate use of PPE, mixing multiple pesticides within a single spraying session ("cocktail mixing"), and improper disposal of chemical containers. These unsafe practices significantly increase toxic exposure through dermal absorption, inhalation, and secondary environmental contamination, thereby elevating occupational health risks (Rother, 2018).

Evidence from occupational health studies in Thailand has shown that inappropriate PPE use during pesticide mixing and spraying is strongly associated with elevated levels of organophosphate metabolites, indicating a greater internal toxic burden among agricultural workers. Moreover, unsafe exposure patterns have been linked to reduced cognitive performance and early neurological impairment (Chittrakul et al., 2022). At the broader epidemiological level, systematic reviews consistently report robust associations between long-term pesticide exposure and a range of chronic health outcomes, including cancer, neurodegenerative disorders, endocrine disruption, and reproductive dysfunction. These findings underscore that unsafe pesticide behaviors should be interpreted not only as individual risk practices, but also as a critical occupational and environmental health policy issue requiring integrated preventive interventions in Thailand's agricultural sector (Mostafalou & Abdollahi, 2017).

According to the World Health Organization (WHO), pesticide poisoning remains a major global public health concern, with millions of cases occurring annually worldwide, disproportionately affecting low- and middle-income countries where occupational safeguards are often limited (World Health Organization, 2020). Earlier WHO estimates suggested approximately one million unintentional pesticide poisoning cases and around 20,000 deaths annually, with the true burden likely underestimated because of underreporting in developing regions (Boedeker et al., 2020). Organophosphate and carbamate pesticides are particularly hazardous because they inhibit cholinesterase enzymes, leading to both acute cholinergic toxicity and long-term neurotoxic sequelae (Robb et al., 2017).

In Thailand, pesticide poisoning continues to represent an important occupational and environmental health issue among agricultural workers. National surveillance and poison-center reports have documented several thousand pesticide poisoning cases annually, with carbamate and organophosphate compounds remaining common causes of occupational exposure (Tongpoo et al., 2015) . Furthermore, blood cholinesterase screening programs conducted among farmers in several agricultural provinces have consistently identified abnormal enzyme levels in approximately 20–30% of tested individuals, reflecting the persistent risk of chronic low-dose exposure and cumulative neurotoxicity (Ministry of Public Health, 2020). These findings highlight the need to strengthen routine biomonitoring, community-based risk communication, and behavioral interventions aligned with Thailand's agricultural safety policies.

Suphan Buri Province, one of Thailand's major rice-producing provinces in the central plain, is a high-priority setting for reducing pesticide risk because its intensive rice cultivation system requires repeated agrochemical applications across multiple cropping cycles. Evidence from studies conducted in Suphan Buri has documented chronic pesticide exposure and abnormal serum cholinesterase profiles among rice farmers, indicating persistent occupational health risks (Suwannahong et al., 2020). The findings reflect a continuing knowledge–practice gap, suggesting that unsafe pesticide behaviors are shaped not only by individual knowledge deficits but also by social norms, community structures, and contextual farming constraints.

From a theoretical perspective, Arnstein's Ladder of Citizen Participation (Arnstein, 1969) posits that meaningful participation fosters empowerment, shared decision-making, and collective ownership of community problems. Complementing this, the Protection Motivation Theory (PMT) (Rogers, 1975, 1983) explains that preventive behavior is influenced by perceived severity, perceived vulnerability, response efficacy, and self-efficacy. In Thai agricultural communities, participatory, multi-component interventions grounded in behavioral theory have demonstrated significant improvements in pesticide-safety behaviors and home-chemical management practices (Raksanam et al., 2012). However, systematically developed and experimentally evaluated community-participatory intervention models specifically tailored to the socio-agricultural context of Suphan Buri remain limited.

Therefore, the study aimed to develop and evaluate a community-participatory model to prevent and control pesticide hazards among farmers in Suphan Buri Province. The study holds both practical and policy significance by generating an evidence-based intervention framework that may reduce occupational health risks, mitigate environmental contamination, and serve as a scalable prototype for implementation in other agricultural regions of Thailand, in alignment with SDG 3 (Good Health and Well-being) and SDG 12 (Responsible Consumption and Production) (United Nations, 2015). By integrating participatory governance with behavior-change theory, the proposed model addresses Thailand's need for context-sensitive, scalable interventions that strengthen farmer safety and sustainable agricultural production.

2. METHODS

The study was conducted in Suphan Buri Province, Thailand, a major agricultural area in the central region where pesticide use is prevalent among farming households.

The population and sample were classified into the three phases of the study as follows.

Phase 1: Situational Analysis of Pesticide Use, Hazard Prevention, and Community-Participatory Pesticide Control

The population and sample in Phase 1 were divided into two groups.

Group 1: The population comprised stakeholder networks involved in hazard prevention and pesticide use control, including representatives from the following sectors: subdistrict headmen and village leaders, president of a Subdistrict Administrative Organization, district agricultural officer, district public health officer, directors of subdistrict health-promoting hospitals, public health academics, subdistrict agricultural officer, director of the public health and environmental division, agricultural cooperative representative, soil volunteer, representatives of pesticide-using farmers, and representatives of pesticide retail vendors. The sample consisted of 19 representatives purposively selected from relevant stakeholders involved in farmers' hazard prevention and pesticide control, including: subdistrict headmen and village leaders (n = 2), president of a Subdistrict Administrative Organization (n = 1), district agricultural officer (n = 1), district public health officer (n = 1), directors of subdistrict health-promoting hospitals (n = 3), public health academics (n = 3), subdistrict agricultural officer (n = 1), director of the public health and environmental division (n = 1), agricultural cooperative representative (n = 1), soil volunteer (n = 1), representatives of pesticide-using farmers (n = 2), and representatives of pesticide retail vendors (n = 2)

Group 2: The population consisted of household heads or household representatives aged 15–60 years who used pesticides in Suphan Buri Province, covering 10 districts, with 73,591 farming households, and the sample size was 276.

2.1. Sampling Procedure

A multistage sampling technique was employed. Initially, cluster sampling was applied to the study population comprising 73,591 agricultural households across 10 districts, distributed among 1,008 villages in Suphan Buri Province. In the first stage, districts were selected using simple random sampling. A complete list of all districts was prepared, and 50% of the districts (5 districts) were randomly selected by lottery. The selected districts were Mueang, Song Phi Nong, Doem Bang Nang Buat, U Thong, and Nong Ya Sai. In the second stage, the sample size was proportionally allocated to each selected district according to the number of households using pesticides. The proportional allocation was calculated and shown in Table 1

Table 1: Proportional allocation of household samples using pesticides, classified by district.

District	Population	Sample size
Mueang District	9,812	62
U Thong	9,579	61
Doem Bang Nang Buat	8,775	55
Song Phi Nong	8,436	53
Nong Ya Sai	7,286	45
Total	43,888	276

Step 3: Eligible farmers in each district were selected using simple random sampling from the sampling frame of participants who met the inclusion criteria until the required sample of 276 farmers was obtained.

Phase 2: Development of the community-participatory model for hazard prevention and pesticide use control among farmers

In Phase 2, 19 purposively selected participants were recruited to participate in the model development process. A participatory workshop employing the AIC process was conducted to develop a community-participatory model for hazard prevention and pesticide use control among farmers. In addition, the study population included farmers from households using pesticides in areas with the highest prevalence of unsafe blood cholinesterase screening results. Two problem-prone areas in Suphan Buri Province with significant pesticide-use issues were purposively selected: Ban Laem Subdistrict, Bang Pla Ma District (N = 957), and Sa Krajom Subdistrict, Don Chedi District (N = 1,250). From these populations, farmers with high-risk or unsafe blood pesticide residue screening results were purposively selected as the experimental group: 30 farmers from Ban Laem Subdistrict, and the control group: 30 farmers from Sa Krajom Subdistrict. The total sample comprised 60 participants.

2.2. Eligibility Criteria

1. Inclusion Criteria: Participants were eligible if they met all of the following conditions: blood screening results indicating high-risk or unsafe pesticide residue levels, resided in either Sa Krajom Subdistrict and Ban Laem Subdistrict for at least 6 months, no visual impairment, no hearing impairment, able to read and write, voluntarily agreed to participate and provided written informed consent, and able to attend all research activities throughout the program
2. Exclusion Criteria: Participants were excluded if they met any of the following conditions: refused to provide consent or withdrew during the study, unable to participate throughout the intervention program and to provide data independently due to communication, cognitive, or health-related limitations, concurrently participating in another intervention or research project with similar characteristics that might influence study outcomes, and unable to fully participate in all stages of the research process, particularly during the model development and participatory evaluation phases

Phase 3: Evaluation of the Community-Participatory Model

The model was evaluated using the same participant groups as in Phase 2. The study sample consisted of 30 farmers from Ban Laem Subdistrict in the experimental group and 30 from Sa Krajom Subdistrict in the control group. Thus, the total number of participants remained 60 farmers, representing the same cohort enrolled during the model development phase.

Conceptual Framework.

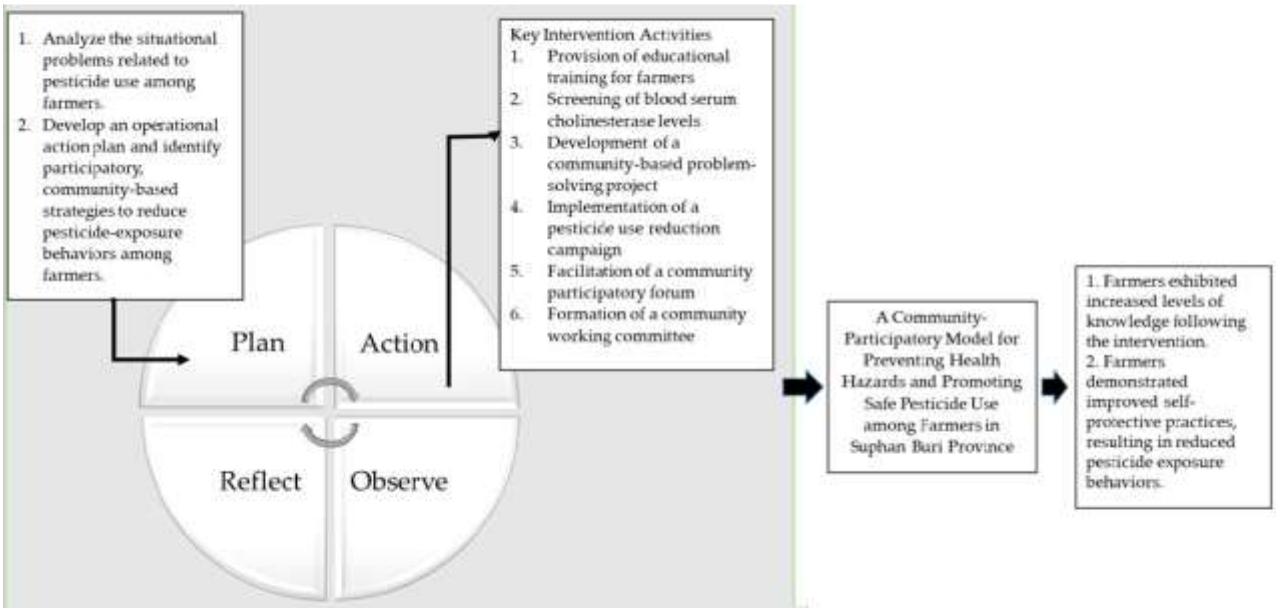

Figure 1: Conceptual framework for the development and evaluation of the community-participatory model.

The conceptual framework of the study was developed by integrating three complementary theoretical foundations. First, the study adopted the principles of Participatory Action Research (PAR) proposed by Kemmis, McTaggart, and Nixon (2014), emphasizing iterative cycles of planning, action, observation, and reflection to facilitate context-sensitive community problem solving. Second, the framework incorporated Arnstein's (1969) concept of Citizen Participation, which underscores empowerment, shared decision-making, and community ownership in addressing local health and environmental challenges. Third, these participatory principles were operationalized through the AIC process (Appreciation–Influence–Control) and theoretically strengthened by Protection Motivation Theory (PMT) proposed by Rogers (1975, 1983), which explains preventive behavior through threat appraisal, coping appraisal, and self-efficacy mechanisms. Together, the integration of these frameworks provided a robust conceptual basis for designing a community-driven behavioral intervention model to strengthen safe pesticide-use practices, reduce occupational health risks, and promote sustainable agricultural safety among farmers (Arnstein, 1969; Kemmis et al., 2014; Rogers, 1975, 1983).

Research Instruments: The research adopted a mixed-methods approach, combining quantitative and qualitative methodologies to ensure a comprehensive exploration of the study objectives. Therefore, the data collection instruments were categorized into three phases of the research process: situational analysis, model development and implementation, and outcome evaluation.

Phase 1: Situational analysis instruments

In Phase 1, which examined the situation of pesticide use, hazard prevention, and community-participatory control of pesticide use among farmers, two sets of research instruments were employed.

Instrument Set 1: Structured interview guide for stakeholder network partners

The first instrument was a structured interview guide developed by the researchers for key stakeholders in the network involved in pesticide use prevention and control. The interview guide consisted of two parts:

Part 1: General information. The section collected background information regarding the stakeholder participants, and Part 2: Key interview issues. The section explored stakeholder perspectives on the following issues:

1. Factors that currently contribute to farmers' lack of knowledge regarding hazard prevention and the safe control of pesticide use.
2. Factors influencing farmers' preventive behaviors related to hazard prevention and pesticide control.
3. Stakeholder perspectives on the current situation and the desirable model of pesticide use prevention and control among farmers through community participation.
4. Recommendations for improving hazard prevention and the community-based control of pesticide use among farmers.

Instrument Set 2: Questionnaire on Knowledge and Preventive Behaviors Related to Pesticide Use: The questionnaire was administered to 276 farmers who reported using pesticides, all of whom were included as the study sample. The second instrument consisted of a researcher-developed questionnaire designed to assess farmers' knowledge and behaviors regarding hazard prevention and the safe use of pesticides. The questionnaire was divided into three sections, comprising 75 items in total. The questionnaire used in the study consisted of three parts, as detailed below:

Part 1: General characteristics of farmers: The section comprised 15 items designed to collect demographic and agricultural background information, including age, sex, marital status, educational level, duration of pesticide use, and reasons for pesticide use.

Part 2: Knowledge of hazard prevention and safe pesticide use: The section included 30 dichotomous items (Yes/No format) assessing farmers' knowledge of hazard prevention and safe pesticide use. Respondents were instructed to select the single most appropriate answer for each item. Each correct response was worth 1 point, while each incorrect response was worth 0 points. The instrument was developed and adapted by the researchers based on an extensive review of relevant literature and previous studies concerning participatory planning and safe pesticide use practices among farmers. The obtained scores were interpreted and categorized according to the criteria adapted from Bloom et al. (2011) as follows: High knowledge level: 0.80–1.00, Moderate knowledge level: 0.60–0.79, and Low knowledge level: 0.01–0.59 (Bloom et al., 2011)

Part 3: Preventive behaviors for hazard prevention and safe pesticide control

The section consisted of 30 items that measured actual behaviors related to hazard prevention and the safe use of pesticides among farmers. The items required respondents to indicate the frequency with which they actually performed each behavior. Responses were rated using a 3-point Likert-type scale: always practice = 3 points, sometimes practice = 2 points, and never practice = 1 point. Behavioral scores were then interpreted into three levels using the same criteria framework: High (0.80–1.00), Moderate (0.60–0.79), and Low (0.01–0.59).

Phase 2: Model development and pilot implementation

In Phase 2, which involved the development of a community-participatory model for hazard prevention and the safe control of pesticide use among farmers, one research instrument was employed, as follows:

Instrument Set 1: Questionnaire on knowledge and preventive behaviors

The instrument used in this phase was a researcher-developed questionnaire designed to assess farmers' knowledge and preventive behaviors related to hazard prevention and the safe use of pesticides. The questionnaire was developed based on an extensive review of relevant literature and was the same instrument previously used in Phase 1 to collect survey data from 276 farmers. In this phase, the instrument was used to measure baseline levels of knowledge and preventive behaviors among farmers in the experimental group prior to implementing the developed model.

Phase 3: Model evaluation

In Phase 3, which evaluated the community-participatory model for hazard prevention and the safe use of pesticides among farmers, two research instruments were used.

Instrument Set 1: Questionnaire on knowledge and preventive behaviors

The first instrument was the researcher-developed questionnaire used to assess farmers' knowledge and preventive behaviors related to pesticide hazard prevention and safe control practices. The instrument had previously been used in Phase 2 to assess both the experimental and control groups and was subsequently re-administered in this phase as a post-intervention measure to evaluate changes following implementation of the model.

Instrument Set 2: Participant satisfaction assessment

The second instrument was a participant satisfaction questionnaire used to assess farmers' perceptions of the training activities in the experimental group during Phase 3 (n = 30).

The questionnaire employed a 5-point Likert rating scale, ranging from 5 = highest level of satisfaction to 1 = lowest level of satisfaction. Satisfaction levels were interpreted using the class interval method based on Best's criterion, as follows: High satisfaction: 3.68–5.00, Moderate satisfaction: 2.34–3.67, and Low satisfaction: 1.00–2.33 (Best, 1977).

3. RESEARCH PROCEDURES AND INSTRUMENT DEVELOPMENT

The researcher developed the data collection instruments as follows.

1) Structured Interview for Key Stakeholders: A researcher-developed structured interview guide was used to collect qualitative data from stakeholders involved in pesticide hazard prevention

and the safe control of pesticide use among farmers. The instrument development process was conducted sequentially as follows: Literature review and theoretical grounding: Relevant principles, theories, and previous studies were reviewed, and the findings were used to draft the interview guide under the supervision of the academic advisor, Conceptual framework development: A conceptual framework was established to guide item construction, interview guide construction: a structured interview guide consisting of open-ended questions was developed to allow respondents to freely express their opinions and describe previous practices. The instrument comprised two sections: section 1: general demographic information of the respondents, completed through short-answer responses based on factual information., section 2: Three open-ended questions addressing (i) the current situation of pesticide hazard prevention and safe control practices among farmers, (ii) factors influencing farmers' knowledge and preventive behaviors, and (iii) recommendations for improving community-based prevention and control measures. The draft instrument was submitted to experts for review and recommendations, and the revised interview guide was evaluated by five experts for content validity using the Index of Item-Objective Congruence (IOC), which ranged from 0.67 to 1.00, indicating acceptable content validity; therefore, the instrument was retained for use.

Questionnaire on knowledge and preventive behaviors: To examine the operational status of pesticide hazard prevention and control practices among farmers, a researcher-developed questionnaire assessing knowledge and preventive behaviors was constructed using the following steps: 1) Review of relevant literature: Relevant theories, concepts, and empirical studies were reviewed, and the findings were used to develop the questionnaire with expert consultation, 2) Framework specification: A conceptual framework for questionnaire development was established, and 3) Questionnaire construction: The questionnaire was divided into three sections:

Section 1: General characteristics: The section included 15 items covering age, sex, marital status, educational level, duration of pesticide use, and reasons for pesticide use.

Section 2: Knowledge of pesticide hazard prevention and safe control: The section consisted of 30 dichotomous items (Yes/No) that required respondents to select the single most appropriate answer.

Section 3: Preventive behaviors related to pesticide hazard prevention and control:

The section contained 30 rating-scale items assessing the extent to which respondents engaged in protective behaviors during their daily agricultural activities. The draft questionnaire was submitted to the academic advisor for review and revision. The revised questionnaire was evaluated by five experts using the IOC method, with acceptable IOC values ranging from 0.67 to 1.00, and the finalized questionnaire was pilot-tested with 30 farmers from Si Prachan District, who were not included in the study sample. Reliability was assessed using Cronbach's alpha, yielding an overall reliability of 0.82, indicating good internal consistency. Final Revision and Field Administration: Following pilot testing, the revised instrument was resubmitted to the panel of experts for further refinement to ensure accuracy, clarity, and completeness. After incorporating the experts' recommendations, the final version of the questionnaire was prepared and administered to 276 farmers, who constituted the study sample.

Phase 2: Model Development and Implementation: The researcher conducted the following procedures.

1. A participatory meeting with expert stakeholders and community network partners was organized using the AIC process to develop a community-participatory model. The model development was based on: 1) the quantitative findings from Phase 1, particularly data on farmers' knowledge and preventive behaviors regarding pesticide use, and 2) the qualitative findings from in-depth interviews with network stakeholders. These two data sources were integrated to formulate a context-specific intervention model. The resulting model consisted of two major implementation components: 1) farmer-focused activities, and 2) community stakeholder engagement activities. A meeting record form was used to document the participatory planning process, stakeholder inputs, and consensus decisions throughout the AIC sessions.
2. The appropriateness of the developed model for pesticide hazard prevention and safe control among farmers was subsequently evaluated through expert consultation, focusing on its feasibility, relevance, and contextual suitability.

The validation procedures were as follows:

1. The expert review panel consisted of five specialists with expertise in public health,

community participation, behavioral interventions, and agricultural safety. These experts reviewed the developed model and provided recommendations to improve its practicality and methodological rigor before field implementation.

2. The instrument used for data collection in this phase was an appropriateness assessment form developed by the researcher and reviewed for suitability by the expert panel. The assessment focused on the feasibility, contextual relevance, clarity, and practical applicability of the developed community-participatory model.
3. Data obtained from the expert review process were analyzed using content analysis to identify key themes, recommendations, and essential components for refining the model. The model derived from Step 1 and subsequently validated by experts was transformed into an activity-based intervention plan aligned with the objectives of preventing pesticide hazards and controlling safe use among farmers. The researcher designed three participatory training and practice-based activities, each delivered once per session, with one full-day workshop per activity (7 hours/session), for a total of three implementation days.

Activity 1: "What Are Pesticides?" The activity aimed to strengthen farmers' knowledge and understanding of pesticide hazards, health effects, and preventive measures. The session employed station-based learning activities, with participants divided into small groups for interactive knowledge exchange and discussion.

Activity 2: "How to Use Pesticides Safely for Both Humans and the Environment": The session focused on promoting safe practices for handling and applying pesticides. Participants engaged in hands-on practical training using real agricultural equipment and protective devices, organized in small-group workshops.

Activity 3: "Pesticides: A Silent Threat That Can Cost Lives": The activity aimed to enhance risk awareness and perceived severity of pesticide exposure among farmers. The session incorporated health role models and farmers who had previously experienced pesticide-related adverse effects, allowing participants to learn from real-life experiences and community exemplars.

All three activities (7 hours/session) were designed to promote capacity building, role-model learning, and real-world application in daily agricultural practices. Each session was held every 2 weeks to allow participants sufficient time to apply the learned practices in real-world settings.

1. 4) A community-wide campaign promoting collective reduction in pesticide use was organized once during the intervention period. The campaign aimed to foster shared community responsibility and strengthen social norms toward safer agricultural practices.
2. 5) A community working committee for pesticide hazard prevention and safe use control was established, and responsibilities included providing consultation and operational guidance, conducting health screenings among farmers, and delivering educational support on safe pesticide use and preventive behaviors. The committee served as the local sustainability mechanism to ensure continued implementation beyond the research period.
3. 6) Knowledge and preventive behaviors were assessed in both the experimental group (n = 30) and the control group (n = 30) using the revised questionnaire developed from Phase 1 findings. The instrument was administered prior to the implementation of the intervention activities to establish baseline levels of knowledge regarding pesticide hazard prevention and preventive behaviors related to safe pesticide use.
4. 7) A participatory action workshop was conducted to implement the planned intervention activities among pesticide-using farmers in the study area. All activities were carried out according to the predefined operational plan developed from the validated model. The development of instruments for data collection to address objective 3 was subsequently undertaken in Phase 3.

Phase 3: Model evaluation

In Phase 3, data were collected using two research instruments designed to evaluate the outcomes of the developed community-participatory model.

Instrument Set 1: Questionnaire on knowledge and preventive behaviors

The first instrument was a questionnaire assessing farmers' knowledge and preventive behaviors related to pesticide hazard prevention and safe control practices. The questionnaire was developed by the researcher by adapting the literature review and the findings of the Phase 1 survey involving 276 farmers.

The instrument's content was further refined to focus on domains that had previously demonstrated low baseline scores, thereby enabling a more sensitive assessment of changes in knowledge and behaviors following implementation of the intervention model, and administered to the experimental group after completion of the intervention to evaluate post-intervention changes in: knowledge regarding pesticide hazard prevention, and preventive behaviors associated with safe pesticide use.

Instrument Set 2: Farmer satisfaction questionnaire

The second instrument was a satisfaction assessment questionnaire administered to the 30 farmers in the experimental group who participated in Phase 2 intervention activities.

The questionnaire was designed to evaluate participants' perceptions of the relevance of the activities, the usefulness of the model, applicability in daily agricultural practice, and overall satisfaction with participation, and was revised by a panel of expert reviewers for content validity assessment, using the Index of Item-Objective Congruence (IOC) method. IOC values ranged from 0.67 to 1.00, indicating acceptable content validity and supporting its use in the final evaluation phase.

Instrument quality assessment

The questionnaire was pilot-tested with 30 farmers who were not included in the study sample, specifically pesticide-using farmers from Si Prachan District, was assess the instrument's reliability using Cronbach's alpha coefficient. The reliability coefficients were as follows: Knowledge domain: $\alpha = 0.78$, Preventive behavior domain: $\alpha = 0.81$, and Overall instrument: $\alpha = 0.82$. These values indicate acceptable to good internal consistency, supporting the reliability of the questionnaire for field implementation. The structured interview guide was submitted to a panel of experts for content validity assessment using the Index of Item-Objective Congruence (IOC) method. The interview instrument achieved an IOC value of 0.94, indicating excellent content validity and confirming its suitability for qualitative data collection.

The researcher conducted the study and collected both quantitative and qualitative data in accordance with the research objectives. The data collection process was organized into three phases, as described below.

Phase 1: Situational Analysis of Farmers' Pesticide Hazard Prevention and Safe Control Practices. The procedures and instruments used in the phase were as follows:

1. Official permission and coordination: A formal letter was issued from the researcher's affiliated institution to the relevant local authorities to request permission and facilitate data collection within the selected district study areas.
2. Baseline survey of current knowledge and behaviors: The current status of farmers' knowledge and preventive behaviors regarding pesticide hazard prevention and safe control was assessed using the researcher-developed questionnaire, which had undergone expert validation and pilot testing in a comparable setting.
3. In-depth stakeholder interviews: In-depth interviews were conducted with community stakeholders in the sample districts using the researcher-developed structured interview guide.
4. Data verification and completeness check: The researcher reviewed all completed questionnaires and interview records to ensure completeness, consistency, and accuracy of responses.
5. A participatory AIC workshop was conducted to develop a preliminary draft of the community-participatory model for pesticide hazard prevention and safe control among farmers.
6. Preparation for Phase 2 implementation: The findings from the situational analysis and the preliminary intervention model were then used as the foundational inputs for Phase 2: Model Development and Field Implementation.

Phase 2: Development and implementation of the community-participatory model

The procedures undertaken in this phase were as follows:

1. Administrative approval and area coordination: Formal letters were issued from the researcher's institution to relevant local agencies to request permission and support for conducting the study in the designated experimental and control districts.
2. Establishment of the community operational committee: A community operational committee for pesticide hazard prevention and safe control was formally appointed by the district chief officer. The committee was responsible for supporting model implementation, local coordination, and sustainability mechanisms.
3. Capacity strengthening of the committee: The committee members underwent a capacity-

strengthening orientation meeting, during which the researcher provided the findings on farmers' knowledge and preventive behaviors obtained from Phase 1, and the preliminary community-participatory prevention model developed from the situational analysis. The process ensured that committee members fully understood the intervention framework and their operational roles.

4. Model implementation and baseline assessment: The developed model was implemented through a community-based pesticide hazard prevention campaign. Prior to the intervention, knowledge and preventive behaviors were assessed in both the experimental group (n = 30) and the control group (n = 30) using the researcher-developed questionnaire refined from the problems identified in Phase 1.
5. Health literacy enhancement activities: A structured health literacy and behavior promotion program was conducted through three participatory workshops and hands-on practice sessions, each delivered as one full-day session (7 hours).

Session 1: Knowledge and understanding enhancement

The first session aimed to strengthen farmers' knowledge and understanding of pesticide-related health hazards and preventive measures through station-based learning activities and small-group discussions. Duration: 7 hours

Session 2: Behavioral skill development

The second session focused on promoting safe preventive behaviors through hands-on practice using real equipment and personal protective devices, delivered in small-group training formats. Duration: 7 hours

Session 3: Awareness and risk perception: The third session aimed to enhance risk awareness and self-protective motivation by learning from health role models, including farmers and individuals affected by pesticide exposure. Duration: 7 hours

All three sessions were designed based on capacity building, role-model learning, and translation into real-life daily agricultural practices.

Each session was conducted at 2-week intervals to support reflection and the application of behavior between sessions.

Phase 3: Outcome evaluation of the community-participatory model

The evaluation assessed the effectiveness of the implemented model and was divided into two major components.

1. Evaluation of knowledge and preventive behaviors: The first component assessed farmers' knowledge and preventive behaviors related to pesticide hazard prevention and safe control following implementation of the intervention. The assessment was conducted using the researcher-developed questionnaire and involved: the experimental group (n = 30) after participation in the knowledge and health behavior promotion activities, and the control group (n = 30) assessed during the same post-intervention period.
2. Participant satisfaction evaluation: The second component evaluated the satisfaction of the experimental group participants with the intervention activities implemented during Phase 2.

3.1. Statistical Analysis

The data were analyzed using both descriptive and inferential statistics, as follows:

Descriptive statistics, including frequency, percentage, mean, and standard deviation (SD), were used to summarize the participants' general characteristics. Inferential statistics, including ANOVA and two-way MANOVA, were performed to examine within-group variance and multivariate changes over time.

4. RESULTS

Phase 1: Situational analysis of pesticide use, hazard prevention, and pesticide control among farmers through community participation

Part 1: Findings from stakeholder network interviews

As summarized in Table 2, the interviews revealed that farmers' insufficient knowledge of pesticide hazard prevention was primarily driven by limited access to information, inadequate extension support, weak participation in farmer groups, and a productivity-oriented reliance on pesticides. Structural barriers, including poor internet connectivity, limited mobile phone ownership, and insufficient outreach personnel, restricted access to timely safety information. In addition, low engagement in collective learning activities and farmers' workload constraints further reduced opportunities for knowledge exchange and preventive education.

Table 2: Situation analysis and stakeholder perspectives on factors associated with insufficient farmer knowledge of pesticide hazard prevention and control.

Factors	Academic network	Community/local network	Farmer/vendor network
Convergent Issues	Limited and inequitable access to information sources Lack of farmer group formation for the development and exchange of academic knowledge	Extension officers provide information inconsistently, with limited coverage and infrequent field outreach Access to internet-based information remains uneven and insufficient Farmers lack a collective organization aimed at reducing pesticide use while simultaneously improving agricultural productivity	Public health and agricultural officers do not provide education on pesticide hazards to all households, and outreach visits are infrequent and lack continuity There is no organized farmer group dedicated to reducing pesticide use while improving agricultural productivity
Divergent Issues	Farmers prioritize higher agricultural productivity while giving limited attention to the potential adverse consequences	Farmers perceived that agricultural production without pesticide use would not yield satisfactory outcomes	Without pesticides, farm operations may not be completed in time, pest infestations may remain uncontrolled, and crop yields may consequently be damaged

As presented in Table 3, the situation analysis and stakeholder perspectives identified financial limitations, prolonged pesticide exposure, and time-related work pressures as the principal factors influencing farmers' health, safety, and pesticide preventive behaviors. Financial constraints reduced farmers' ability to obtain complete personal protective equipment (PPE), while low risk perception further discouraged consistent use. Prolonged exposure duration was also recognized as a major determinant of adverse health risk, although some experienced farmers partially mitigated the risk through accumulated practical knowledge.

In addition, agricultural time pressures encouraged convenience-based practices, including reliance on herbicides instead of manual weeding and mixing multiple pesticide products in a single spraying session. These findings collectively suggest that preventive behaviors are shaped not only by knowledge but also by economic capacity, occupational exposure patterns, and the structural demands of agricultural production.

Table 3: Situation analysis and stakeholder perspectives on factors affecting farmers' health, safety, and pesticide preventive behaviors.

Factors	Academic network	Community/local network	Farmer/vendor network
Budget: Convergent Issues	Farmers often lack sufficient financial resources to purchase complete tool sets and PPE for pesticide spraying.	Some participants noted that farmers may either fail to recognize the importance of PPE or lack the financial means to purchase it.	As a result, some farmers purchase only the items they perceive as absolutely necessary, resulting in incomplete use of protective equipment during pesticide application.
Budget: Points of Divergence	Some participants proposed allocating specific budget funds to purchase protective equipment for pesticide safety.	Others argued that the existing financial support does not adequately meet farmers' actual needs, particularly regarding the type and quantity of protective equipment required.	Another concern raised was that some support mechanisms are provided as interest-bearing group-based loan funds, which may inadvertently increase farmers' debt burden over time.
Duration of pesticide exposure: Convergent Issues	Farmers who have been engaged in agricultural work for a longer period are more likely to experience adverse effects from pesticide exposure.	At the same time, long-term farming experience may enable some farmers to develop practical coping strategies for managing the impacts of pesticide use.	Conversely, limited time available for agricultural work often creates time pressure, leading farmers to adopt faster but potentially unsafe practices, such as using herbicides instead of manual

			weeding and mixing multiple pesticides in a single spraying session.
Duration of pesticide exposure: Point of Divergence	Some participants emphasized that farmers who consistently wear protective equipment are less likely to experience pesticide toxicity and related health hazards.	In contrast, others highlighted that many farmers lack access to adequate protective equipment, partly because certain items are expensive.	It was also noted that some types of protective equipment are not only costly but also difficult to use and inconvenient during farm work, which may discourage consistent use.

As summarized in Table 4, key informants consistently described pesticide use as a structurally embedded practice in local agricultural systems, particularly in large-scale farming where labor shortages and cost constraints limit feasible alternatives. Participants emphasized that pesticides remain essential for efficiently managing extensive cultivation areas, whereas small-scale farmers were perceived as having greater flexibility to adopt organic or low-chemical practices.

Stakeholders also highlighted concerns regarding insufficient regulation of pesticide distribution channels and the long-term health consequences of chronic exposure. Although acute symptoms such as headache, dizziness, and throat irritation were commonly recognized as transient, participants expressed greater concern about cumulative exposure effects, including the potential development of serious chronic diseases such as cancer.

Table 4: Situation analysis and stakeholder perspectives on community participation in pesticide hazard prevention and control.

Factors	Academic network	Community/local network	Farmer/vendor network
Pesticide Use: Convergent Themes	Farmers are increasingly using pesticides on a widespread scale, to the extent that some highly hazardous substances have been officially prohibited by the government.	Pesticide use remains particularly common among large-scale farmers, whereas small-scale farmers have increasingly begun to shift toward organic farming practices.	Farmers continue to rely on pesticides to achieve high crop yields and timely production schedules, especially because such chemicals are readily accessible through local retail outlets.
Pesticide Use: Divergent Themes	Some farmers continue to use pesticides in unsafe ways, with many not consistently wearing PPE during application.	In contrast, another perspective indicated that farmers are increasingly interested in reducing pesticide use and paying greater attention to organic farming practices.	Another viewpoint emphasized that pesticide use remains essential to maintain adequate crop yields, as failure to use them may lead to reduced productivity and financial losses in agriculture.
Health Impacts: Convergent Themes	The immediate health effects of pesticide exposure are often not clearly recognized; however, the long-term effects are perceived as more serious and may include chronic illnesses, such as cancer.	Participants also highlighted significant environmental impacts, particularly when pesticide residues are washed into canals, ponds, and swamps after spraying, leading to unpleasant chemical odors that spread throughout the surrounding area. Such exposure may contribute to symptoms including headache, dizziness, and loss of appetite.	Farmers involved in mixing, spraying, and cleaning pesticide equipment often wash the equipment in nearby water sources such as canals, ponds, and reservoirs, leading to chemical contamination of these areas. The persistent odor of pesticides in the vicinity was also associated with headache and dizziness among nearby residents and workers.
Health Impacts: Divergent Themes	One perspective emphasized the existence of health impact surveillance systems, particularly through farmers' health screening using blood cholinesterase testing as a biomarker of pesticide exposure.	Another viewpoint suggested that short-term health effects occur among some farmers, including symptoms such as a dry throat and skin rashes, whereas the long-term health consequences remain less well recognized.	In contrast, some participants reported that farmers often do not perceive short-term health effects, largely because observable symptoms are absent or not sufficiently pronounced immediately after exposure.

Table 5 presents the general characteristics of the 276 study participants. The sample was predominantly male (75.0%), with the largest proportion aged 45–54 years (31.4%). Most participants were married (78.3%) and had completed primary education (88.8%), reflecting a relatively low level of formal educational attainment.

Regarding health-related behaviors, the majority were non-smokers (70.7%) and non-drinkers (56.9%). Regarding agricultural roles and responsibilities, pesticide spraying was the most frequently reported activity (93.8%), indicating a high level of direct occupational exposure. Most participants reported relying on pesticide vendors as their primary source of pesticide-related information (81.6%), while the largest proportion had 11–20 years of pesticide use experience (43.1%), suggesting prolonged cumulative exposure. More than half of participants (57.2%) reported spending less than USD 410 on pesticides in the previous six months. The most commonly cited reasons for pesticide use were weed control (99.3%), control of insects and other pests or diseases (98.9%), and recommendations from pesticide vendors (97.5%) and fellow farmers (88.4%). In addition, 44.0% indicated that their pesticide use decisions were influenced by media advertisements.

Concerning consultation sources for plant disease and pest management, the majority of participants reported receiving advice primarily from pesticide vendors (62.1%), underscoring the central role of these vendors in shaping farmers' pesticide-related decisions and practices. Despite the high prevalence of pesticide exposure, only 8.7% of participants reported experiencing pesticide-related health problems during the previous six months. The relatively low proportion may reflect underreporting, limited symptom recognition, or the normalization of mild exposure effects among farmers.

In terms of pesticide container disposal practices, the most commonly reported method was collecting and selling used containers to recycling buyers (64.6%). Although this practice may reduce open environmental contamination, it also underscores the need for standardized, safe disposal systems to minimize secondary exposure risks.

Table 5: General characteristics of the study participants (n = 276).

General characteristics	n	%
1. Age		
15 - 24 years	8	2.9
25 - 34 years	29	10.5
35 – 44 years	86	31.2
45 – 54 years	87	31.4
55 – 64 years	66	23.8
2. Gender		
Male	207	75.0
Female	69	25.0
3. Married status		
Single	2	0.7
Married	216	78.3
Widowed/Divorced	58	21.0
4. Educational attainment		
Primary education	245	88.8
Secondary education / Vocational certificate	26	9.4
Higher vocational diploma / Associate degree	3	1.1
Bachelor's degree or higher	2	0.7
5. Smoking status		
Current smoker	81	29.3
Non-smoker	195	70.7
6. Alcohol consumption		
Current drinker	119	43.1
Non-drinker	157	56.9
7. Roles and responsibilities in agricultural activities (multiple responses allowed)		

Pesticide spraying	260	93.8
Pesticide mixing	163	58.8
Irrigation and water release	126	45.5
Crop harvesting	52	18.8
Seed dibbling (seed placement in planting holes)	59	21.3
Soil tillage	113	40.8
Crop trimming and product packaging	162	58.5
8. Sources of Information on Pesticides (multiple responses allowed)		
Neighbors	123	44.4
Pesticide vendors	226	81.6
Government officials	37	13.4
9. Channels through which information about pesticides is received from social media (multiple responses allowed):		
Television	55	19.9
Radio	168	60.6
Leaflets	149	53.8
Posters	60	21.7
Internet	85	30.7
10.1 Duration of pesticide use:		
1–10 years	82	29.7
11–20 years	119	43.1
21–30 years	66	29.6
31 years or more	9	5.0
10.2 Agricultural land area:		
0.1 - 1.6 hectares	105	37.9
1.7 - 3.3 hectares	104	37.9
3.4 - 4.8 hectares	41	14.8
4.9 - 6.4 hectares	19	6.9
More than 6.5 hectares	7	2.5
11. Expenditure on purchasing pesticides for household agricultural use over the past six months		
Less than 410 USD	158	57.2
Between 411 – 619 USD	96	34.8
Between 620 – 928 USD	13	4.7
More than 929 USD	9	3.3
12. Reasons for using pesticides in agriculture (multiple responses allowed)		
To control weeds	275	99.3
To control insects and other pests/diseases	274	98.9
To enhance productivity/yield	272	98.1
Based on recommendations from pesticide vendors	270	97.5
Influenced by advertisements through various media	122	44.0
Based on recommendations from fellow farmers	245	88.4
13. In the past 6 months, from whom or which sources have you received advice or consultation regarding the management of plant diseases or pests? (multiple responses allowed)		
Government officers/academics (e.g., from the municipality or district agricultural office)	123	44.4
Pesticide vendors	172	62.1
Fellow farmers	111	40.0
14. In the past 6 months, have you experienced any health problems related to the use of pesticides in your agricultural practices?		
Yes	24	8.7
No	252	91.3
15. In the past 6 months, how have you disposed of pesticide containers? (You may select more than one answer.)		
Buried	77	27.8

Burned	106	38.2
Collected and sold to recycling buyers	179	64.6
Disposed of indiscriminately in the fields without proper treatment	57	20.6
Placed in garbage bins for municipal collection and disposal	8	2.8

Section 3: Situation of health and safety protection from chemical use among farmers

Part 1: Knowledge of pesticides

Table 6 presents the distribution of farmers' knowledge regarding health risk prevention related to pesticide use among 276 participants. Overall, the findings demonstrated that farmers had a high level of knowledge concerning pesticide-related health risk prevention, with an overall mean score of 0.84.

Pre-application practices

Knowledge related to pre-application practices was generally high, with a mean score of 0.83. Farmers demonstrated strong knowledge regarding the purchase of properly labeled chemical products (mean = 0.97), the inspection of spraying equipment before use (mean = 0.93), the avoidance of opening pesticide containers with the mouth (mean = 0.92), and the mixing of chemicals in well-ventilated areas (mean = 0.90).

However, several items remained at only a moderate level, particularly knowledge related to standing upwind while mixing chemicals (mean = 0.62), standing upwind during spraying (mean = 0.67), and wearing protective boots to prevent dermal absorption (mean = 0.64). These findings suggest persistent gaps in practical knowledge related to personal protective behaviors during the preparation stage.

4.1. During Chemical Application

Knowledge during the chemical application phase was also high, with a mean score of 0.89. Participants showed high awareness of several critical protective measures, including wearing protective goggles (mean = 0.94), avoiding eye and skin contact during spraying (mean = 0.96), changing into clean clothes immediately after spraying (mean = 0.96), and safe storage of chemicals away from children and pets (mean = 0.95).

Nevertheless, knowledge regarding avoiding spraying under strong wind conditions (mean = 0.71) and cleaning spraying equipment before storage (mean = 0.78) remained only moderate. These areas may represent key opportunities for targeted intervention, particularly in reducing chemical drift and secondary exposure risks.

4.1.2. Post-application practices and health risk awareness

For post-application practices and health risk awareness, the overall knowledge level remained high, with a mean score of 0.87. Farmers demonstrated a strong understanding of proper avoidance of cleaning equipment in public water sources (mean = 0.92), the multiple exposure pathways by which pesticides enter the human body (mean = 0.94), and the recognition of acute symptoms following pesticide exposure (mean = 0.90).

A notable exception was knowledge of the long-term bioaccumulation of toxic substances resulting from prolonged pesticide use, which remained moderate (mean = 0.66). This finding suggests that although farmers are familiar with immediate exposure risks, awareness of chronic health consequences remains insufficient.

4.1.3. Health hazard awareness

Knowledge of health hazards was consistently high across all items, with an overall mean score of 0.90. Participants demonstrated strong awareness of the three main routes of pesticide entry into the body, long-term toxic accumulation, risks associated with incorrect dosage measurement, and symptoms of pesticide poisoning. The highest score was observed for the recognition that mixing multiple pesticides during a single spraying session may increase exposure to toxic residues (mean = 1.00).

Table 6: Percentage distribution of farmers classified by their knowledge of health risk prevention related to pesticide use (n = 276).

Knowledge of farmers regarding health risk prevention from chemical use	**Mean**	**Interpretation**
Pre-application practices		
1. Purchasing chemical products that are properly labeled, including warnings and ingredient information.	0.97	High

2. Inspecting spraying equipment prior to use to prevent chemical leakage and exposure.	0.93	High
3. Avoiding the use of the mouth to open bottles or containers of chemicals to prevent accidental ingestion or contamination.	0.92	High
4. Mixing chemicals in open or well-ventilated areas to reduce the dispersion of chemical fumes or particles.	0.90	High
5. Using chemical substances in accordance with recommendations provided by government officials to reduce potential health hazards.	0.88	High
6. Preparing and mixing each type of chemical according to the prescribed ratios before every application.	0.88	High
7. Identifying the type of pests prior to purchasing chemicals in order to minimize risk factors associated with chemical use.	0.87	High
8. Recognizing that mixing multiple chemicals in a single application may increase the intensity of unpleasant odors.	0.82	High
9. Standing upwind during chemical spraying to reduce exposure to airborne chemicals.	0.67	Moderate
10. Wearing protective boots to prevent dermal absorption of chemicals.	0.64	Moderate
11. Standing upwind while mixing chemicals to minimize inhalation or bodily exposure.	0.62	Moderate
Total mean of pre-application practices	0.83	High
During chemical application		
12. If equipment damage is detected during spraying, and the damage is minor, the application should be completed before proceeding with repairs.	0.96	High
13. Avoid rubbing the eyes or scratching the skin during chemical application.	0.96	High
14. Changing into clean clothing immediately after chemical application to prevent chemical exposure.	0.96	High
15. Storing chemicals away from children and pets to prevent accidental exposure.	0.95	High
16. Bathing in public water sources (e.g., streams, ponds, canals, or swamps) after working with chemicals.	0.95	High
17. Wearing protective goggles during spraying to prevent chemical droplets from entering the eyes.	0.94	High
18. Avoiding rest breaks during spraying, as this may increase the risk of work-related accidents.	0.92	High
19. Washing clothing used during chemical spraying separately from regular clothing.	0.88	High
20. Refraining from using the mouth to blow or unclog spray nozzles to prevent ingestion of chemicals.	0.86	High

21. Wearing a safety helmet during chemical application to protect against falling objects.	0.86	High
22. Cleaning and spraying equipment thoroughly before storage after each use.	0.78	Moderate
23. Avoid chemical spraying under strong wind conditions to minimize chemical drift.	0.71	Moderate
Total mean of practices during chemical application	0.89	High
Post-application practices and health risk awareness		
24. Destroying pesticide containers by open-air burning.	0.96	High
25. Recognizing that pesticides can enter the human body through three primary routes: ingestion, inhalation, and dermal absorption.	0.94	High
26. Avoiding the cleaning or spraying of equipment in public water sources.	0.92	High
27. Recognizing that mixing multiple pesticides in a single application may increase the level of toxic residue exposure.	0.90	High
28. Identifying common symptoms following pesticide exposure, such as dizziness, chest tightness, difficulty breathing, and vomiting, which may indicate adverse health effects.	0.90	High
29. Acknowledging that improper mixing of pesticides without adhering to recommended dosages can result in higher concentrations, thereby increasing health risks.	0.84	High
30. Understanding that prolonged use of pesticides may lead to the accumulation of toxic residues in the body, resulting in long-term adverse health effects.	0.66	Moderate
Total mean of post-application practices	0.87	High
Health hazard awareness		
34. Mixing multiple pesticides during a single spraying session may increase exposure to toxic residues.	1.00	High
31. Pesticides can enter the body through three main routes: ingestion, inhalation, and skin absorption.	0.90	High
32. Long-term use of pesticides can lead to bioaccumulation of toxic substances, causing chronic health impacts.	0.90	High
33. Failure to measure pesticides according to recommended proportions may increase chemical concentration and associated health risks.	0.90	High
35 Common symptoms observed after pesticide exposure include dizziness, chest tightness, breathing difficulty, and vomiting.	0.90	High
Total mean of health hazard awareness	**0.92**	High

Table 7 presents the distribution of farmers by their level of knowledge regarding health risk prevention from pesticide use among the 276 study participants.

The findings indicate that the majority of farmers demonstrated a high level of knowledge, with 213 participants (77.2%) achieving mean scores in the 0.80–1.00 range. This suggests that most respondents had a strong understanding of essential principles for preventing health risks associated with pesticide use, including safe handling practices, exposure prevention, and awareness of potential health hazards.

A smaller proportion of participants, 50 farmers (18.1%), were classified as having a moderate level of knowledge (mean = 0.60–0.79). The group may possess a general understanding of pesticide-related health protection; however, certain aspects of practical application and risk recognition may remain incomplete and warrant further educational reinforcement.

Only 13 participants (4.7%) were categorized as having a low level of knowledge (mean = 0.01–0.59), indicating limited awareness and understanding of preventive measures related to pesticide exposure. Although this proportion is relatively small, it remains a critical subgroup requiring targeted intervention due to their heightened vulnerability to unsafe pesticide practices and associated health risks.

Table 7: Levels of knowledge regarding health risk prevention from chemical use among the sample of farmers (n = 276).

Knowledge of health risk prevention from chemical use among farmers	Analysis Results	
	Number	Percentage
High level (mean score = 0.80 – 1.00)	213	77.2
Moderate level (mean score = 0.60 – 0.79)	50	18.1
Low level (mean score = 0.01 – 0.59)	13	4.7

Part 2: Behaviors related to health and safety protection from chemical use among farmers

Table 8 presents the mean scores of behaviors related to health and safety protection from pesticide use among the study participants (n = 276), classified into four behavioral domains: pre-application behaviors, behaviors during chemical application, post-application behaviors, and health impact–related behaviors.

In the pre-application domain, the overall mean score was at an incorrect level (mean = 1.52), indicating inadequate adherence to safe practices prior to pesticide use. Several critical preventive behaviors were performed incorrectly, including assessing pest types before purchasing chemicals, studying chemical composition before use, mixing pesticides according to label instructions, inspecting spraying equipment, consulting agricultural officers or pesticide vendors, and standing upwind during pesticide mixing. Notably, the behavior with the highest appropriate score in this domain was avoiding using the mouth to open chemical containers (Mean = 2.58), which was interpreted as correct.

For behaviors during chemical application, the overall mean score was moderate (mean = 1.67). Participants demonstrated suboptimal use of PPE, including aprons, gloves, long-sleeved shirts, and trousers. Unsafe practices, such as smoking during spraying, also remained at an unacceptable level. However, some protective behaviors were performed relatively well, particularly standing upwind during spraying (mean = 1.33) and avoiding using the mouth to unclog spray nozzles (mean = 2.58), both of which were categorized as correct. Avoiding spraying under strong wind conditions was performed at a moderate level (mean = 1.72).

Regarding post-application behaviors, the overall mean score was also moderate (mean = 1.73). Several essential protective behaviors remained inadequate, including washing work clothing separately, changing clothes immediately after spraying, storing chemicals safely, properly disposing of chemical containers, and avoiding equipment cleaning in public water sources. Nonetheless, participants demonstrated relatively appropriate behavior in avoiding bathing in public water sources after pesticide work (mean = 2.21, correct). Moderate-level practices were also observed in rinsing empty containers before disposal, reusing them, and storing leftover mixed chemicals for future use.

In the domain of health impact–related behaviors and health hazard awareness, the overall mean score was moderate (mean = 2.27). Participants showed better recognition of abnormal symptoms and unsafe contact behaviors during pesticide exposure. Specifically, scratching the head or wiping sweat with contaminated hands during spraying (mean = 2.49) and recognition of abnormal skin symptoms such as rashes, itching, blisters, or skin cracks (mean = 2.49) were interpreted as correct. In addition, awareness of post-exposure symptoms, including dizziness, chest tightness, dyspnea, and vomiting, was moderate (mean = 2.26).

Overall, the mean behavioral score was 2.34, indicating that participants' pesticide-related health and safety protection behaviors were at a correct level. However, the domain-specific findings reveal persistent gaps, particularly in pre-application preparation and post-application decontamination practices, suggesting the need for targeted behavioral interventions and practical safety training programs.

Table 8: Mean scores of behaviors related to health and safety protection from chemical use among the sample group (n = 276).

Behaviors related to health and safety protection from chemical use	Mean	Interpretation
Pre-application behaviors		
1. Mixing multiple chemicals in a single spraying session.	1.42	Incorrect
2. Assessing the type of pests prior to purchasing chemicals.	1.25	Incorrect
3. Studying the types and composition of chemicals before use.	1.23	Incorrect
4. Mixing chemicals according to the recommended ratios specified on the label.	1.20	Incorrect
5. Reading and fully understanding label instructions prior to use.	1.24	Incorrect
6. Using bare hands to mix chemicals, resulting in skin irritation.	2.00	Moderate
7. Inspecting spraying equipment prior to use to prevent chemical leakage and exposure.	1.35	Incorrect
8. Consulting agricultural officers or chemical vendors when uncertain about pesticide use before application.	1.31	Incorrect
9. Standing upwind while mixing pesticides.	1.32	Incorrect
10. Using the mouth to open bottles or containers of chemicals during mixing.	2.58	Correct
11. When transferring chemicals into other containers, it is important to properly label them with details regarding the substance and instructions for use.	1.68	Moderate
Total mean of pre-application behavior	1.52	Incorrect
During chemical application behaviors		
12. Wearing appropriate protective aprons/gloves when handling pesticides or hazardous substances.	1.18	Incorrect
13. Wearing long-sleeved shirts and long trousers to prevent dermal exposure to chemicals or spray droplets.	1.21	Incorrect
14. Taking breaks to smoke, drink water, or eat during work.	2.00	Moderate
15. Smoking while spraying chemicals.	1.20	Incorrect
16. Wearing a hat during spraying to protect against falling objects.	1.83	Moderate
17. Wearing a mask covering the mouth and nose when exposed to hazardous substances (e.g., chemical dust or droplets).	1.37	Moderate
18. Standing upwind during spraying to minimize exposure to chemical drift.	1.33	Correct
19. Avoiding spraying under strong wind conditions.	1.72	Moderate
20. Using the mouth to blow or unclog spray nozzles during application.	2.58	Correct
Total mean of behavior during chemical application	1.67	Moderate
Post-application behaviors		

21. Bathing in public water sources (e.g., streams, ponds, canals, or swamps) after working with chemicals.	2.21	Correct
22. Washing clothing used during spraying separately from regular clothing.	1.18	Incorrect
23. Changing into clean clothing immediately after spraying to prevent chemical exposure.	1.32	Incorrect
24. Inspecting containers for leaks after chemical use.	1.36	Incorrect
25. Storing chemicals safely away from children, pets, and open flames.	1.13	Incorrect
26. Disposing of empty chemical containers by burying them in pits and covering them securely with soil.	1.53	Incorrect
27. Cleaning and spraying equipment in public water sources.	1.33	Incorrect
28. Rinsing empty chemical containers before disposal.	2.09	Moderate
29. Reusing empty chemical containers for storing water or other substances to reduce costs.	2.29	Moderate
30. Storing leftover mixed chemicals for future use.	2.07	Moderate
Total mean of post-application behavior	1.73	
31. Experiencing symptoms such as dry throat, sore throat, or coughing after pesticide application.		Moderate
32. Rubbing the eyes with hands during spraying when foreign particles enter the eyes.	2.21	Moderate
33. Scratching the head or wiping sweat with hands during chemical application.	2.49	Correct
34. Experiencing abnormal symptoms during spraying, such as skin rashes, itching, blisters, or cracked skin.	2.49	Correct
35. Experiencing abnormal symptoms after spraying, including dizziness, chest tightness, difficulty breathing, and vomiting.	2.26	Moderate
Total mean of behavior related to health impacts	2.27	Moderate
Total mean of Behavior	2.34	Correct

Phase 2: Development and Pilot Implementation of a Community-Participatory Model for Preventing Health Hazards from Pesticide Use among Farmers

The second phase of the study focused on developing and pilot implementing a community-participatory model to prevent health hazards associated with pesticide use among farmers. In this phase, the developed model was implemented with the experimental group for 4 weeks, followed by a 2-week sustainability follow-up, resulting in a total intervention duration of 6 weeks. The analysis of Phase 2 was divided into two main components: 1) model development, and 2) outcomes of model implementation.

Part 1: Model Development

The developed model for preventing pesticide-related health hazards among farmers through community participation comprised three major components.

Component 1: Theoretical and Conceptual Foundations

The first component was grounded in the community participation framework of Cohen and Uphoff (1977)(Cohen & Uphoff, 1977) , which conceptualizes participation into four dimensions:1) decision-making participation, 2) implementation participation, 3) benefit-sharing participation, and 4) evaluation participation. In addition, the model incorporated Prentice-Dunn and Rogers' Protection Motivation Theory (Prentice-Dunn & Rogers, 1986), emphasizing four key cognitive processes: 1) perceived severity, 2) perceived susceptibility, 3) response efficacy, and 4) self-efficacy. These theoretical perspectives served as the foundation for designing the health and safety protection model related to pesticide use among farmers. Following the participatory meetings between the researchers and community stakeholders, informed by Phase 1 findings, consensus was reached on the major problems associated with pesticide use. Subsequently, a series of intervention activities was collaboratively planned through a focus group–based participatory process, resulting in the development of an activity package for implementation.

Component 2: Activity Package

The second component consisted of a three-activity intervention package designed to improve knowledge, preventive behaviors, and awareness of health risks among pesticide-using farmers.

Activity 1: "What Are Pesticides?"The activity aimed to enhance farmers' knowledge and understanding of pesticide use and the prevention of health and safety impacts. The activity was delivered through station-based educational learning sessions in small groups.

Activity 2: "How to Use Pesticides Safely for Both Users and the Environment." The activity focused on promoting appropriate preventive behaviors related to pesticide use. It involved hands-on practical training using real equipment and field-based demonstrations, conducted in small groups.

Activity 3: "Pesticides: A Silent Killer That Can Take Your Life If You Are Careless": The activity was designed to strengthen farmers' awareness of the long-term health consequences of pesticide exposure. The sessions incorporated health role models among farmers and individuals who had previously experienced pesticide-related adverse effects, thereby using real-life experiences to reinforce risk perception and behavioral change. The intervention activities were conducted once every 2 weeks, with the total research duration spanning 6 weeks. Each session, including ice-breaking exercises and recreational group activities, lasted approximately 7 hours.

Component 3: Participatory Network Engagement: The third component involved participatory planning by a multi-stakeholder community network. The network consisted of 21 key stakeholders representing sectors relevant to farmers' occupational health and safety in Sa Krachom Subdistrict, Don Chedi District, Suphan Buri Province. These stakeholders included: village headmen and community leaders (n = 6), the president of the Subdistrict Administrative Organization (n = 1), the district agricultural officer (n = 1), the district public health officer (n = 1), directors of subdistrict health-promoting hospitals (n = 2), public health academics/practitioners (n = 2), a subdistrict agricultural officer (n = 1), the director of the public health and environmental division (n = 1), an agricultural cooperative representative (n = 1), a volunteer soil doctor (n = 1), farmer representatives using pesticides (n = 2), and pesticide retailer representatives (n = 2). These stakeholders participated in joint planning meetings, contributing to the design, contextual adaptation, and implementation of the intervention model.

4.2. Final Developed Model

Based on findings from Phase 1 and Phase 2, the researchers established a community-participatory model to prevent health and safety impacts from pesticide use among farmers, as illustrated in Figure 2.

Figure 2: Community-participatory model for preventing health hazards from pesticide use among farmers.

The draft model was further validated through field implementation in a high-risk village setting. A community participatory meeting was conducted using the AIC approach to collaboratively identify intervention activities that were congruent with the local sociocultural and agricultural context. The process resulted in the finalization of a community-participatory model for preventing pesticide-related health and safety hazards among farmers, as detailed below:

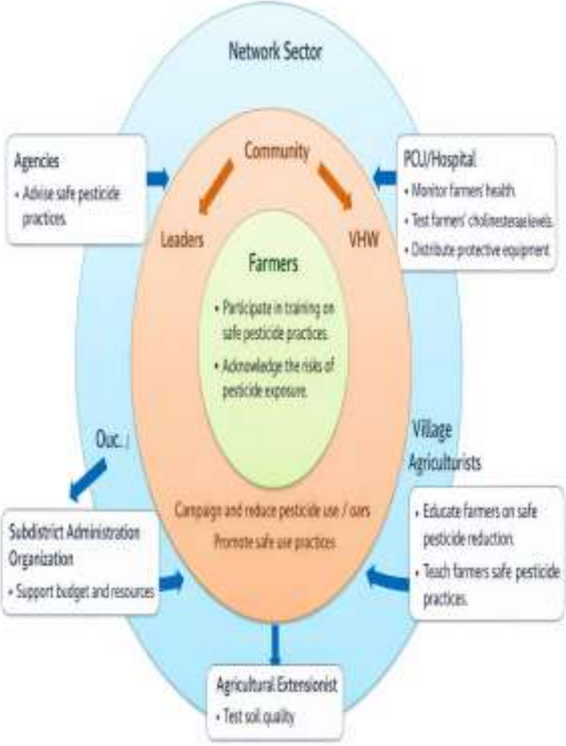

Figure 3: Illustrates the community-participatory model for preventing health and safety hazards associated with pesticide use among farmers.

Following the development and contextual validation of the model, the intervention was implemented through a structured activity package designed to strengthen farmers' preventive behaviors regarding pesticide-related health and safety risks. The intervention was delivered to the experimental group, comprising 30 farmers, as a series of participatory workshop sessions conducted once per week, with each major activity phase scheduled at two-week intervals to allow for reflection and reinforcement of practice. The activity package focused on enhancing knowledge, risk awareness, and practical safety behaviors related to pesticide handling across pre-application, application, and post-application phases. To evaluate the model's effectiveness, farmers' protective health and safety behaviors related to pesticide use were assessed at three time points: before the implementation of the model (baseline), immediately after the intervention, and at a 4-week follow-up to assess the sustainability of behavioral changes over time. This follow-up assessment provided additional evidence of the model's potential to promote sustained improvements in safe pesticide practices among farmers.

Section 2: Results of model implementation

Part 1: Results of general data analysis

Table 9 presents the number and percentage distribution of the general characteristics of farmers in the experimental group (n = 30) and the control group (n = 30). Overall, the baseline characteristics of the two groups were generally comparable across demographic, behavioral, and agricultural practice variables.

Regarding age distribution, participants in both groups were predominantly middle-aged adults. In the experimental group, the largest proportion was aged 35–44 years (40.0%), whereas in the control group, the majority were aged 45–54 years (33.3%), followed by 55–64 years (30.0%). With respect to gender, both groups had an identical distribution, with 70.0% male and 30.0% female participants.

For marital status, most participants in both groups were married or cohabiting, accounting for 83.3% in the experimental group and 86.7% in the control group. In terms of educational attainment, primary education was the predominant level in both groups, although it was more common in the control group (86.7%) than in the experimental group (70.0%). Secondary or vocational education was slightly higher in the experimental group (23.3%) than in the control group (6.7%).

Regarding health-related behaviors, the majority of participants in both groups were non-smokers (experimental: 66.7%; control: 63.3%) and reported no alcohol consumption (experimental: 63.3%; control: 56.7%). These findings suggest relatively similar lifestyle risk profiles between the two groups.

Regarding roles and responsibilities in agricultural activities, chemical spraying was the most frequently reported task in both groups, particularly in the control group (96.7%) compared with the experimental group (86.7%). Likewise, chemical mixing was commonly reported in both groups (experimental: 73.3%; control: 76.7%), reflecting the participants' substantial direct exposure to pesticide-related tasks.

For pesticide-related information, chemical vendors were the primary source in both groups (experimental: 86.7%; control: 90.0%). Similarly, radio and television were the dominant media channels for receiving pesticide-related information, particularly in the control group. Internet use was identical across both groups (40.0%), indicating comparable digital access.

Concerning pesticide use experience, the experimental group most commonly reported 1–10 years of pesticide use (40.0%), whereas the control group more frequently reported 11–20 years (46.7%). Regarding agricultural land area, the majority of farmers in both groups cultivated relatively small holdings, with 1.0–1.6 hectares the most common category (experimental: 50.0%; control: 43.3%).

In terms of household expenditure on pesticides in the previous six months, the largest proportion of the experimental group reported spending less than 410 USD (56.7%), whereas the control group was more evenly distributed across less than 410 USD (40.0%) and 411–619 USD (46.7%).

Regarding the reasons for pesticide use, nearly all participants in both groups reported using pesticides for weed control and insect and plant disease control, indicating strong similarity in agricultural decision-making patterns. In addition, many participants reported using pesticides to enhance crop productivity, particularly in the experimental group (76.7%).

For consultation sources related to plant disease and pest management, pesticide vendors remained the most frequently cited source in both groups, followed by agricultural officers/academics and fellow farmers. This pattern suggests that both formal and informal advisory networks play important roles in pesticide decision-making.

Regarding pesticide-related health problems in the past six months, only 6.7% of participants in each group reported experiencing such problems, indicating identical short-term self-reported health outcomes at baseline.

Finally, regarding pesticide container disposal practices, unsafe disposal behaviors remained common in both groups. The most frequently reported methods included collecting and selling containers to recycling buyers (experimental: 73.3%; control: 60.0%) and disposing of containers indiscriminately in agricultural fields (experimental: 66.7%; control: 73.3%), highlighting persistent environmental health concerns across both groups.

Table 9: Number and percentage distribution of general characteristics of farmers in the experimental and control groups (n = 60).

General characteristics	**Experimental group (n = 30)**		**Control group (n = 30)**	
	Number	Percentage	Number	Percentage
1. Age				
15–24 years	2	6.7	2	6.7
25–34 years	4	13.3	2	6.7
35–44 years	12	40.0	7	23.3
45–54 years	6	20.0	10	33.3
55–64 years	6	20.0	9	30.0
2. Gender				
Male	21	70.0	21	70.0
Female	9	30.0	9	30.0
3. Marital Status				
Single	1	3.3	1	3.3
Married / Cohabiting	25	83.3	26	86.7
Widowed / Divorced	4	13.3	3	10.0
4. Educational Level				
Primary education	21	70.0	26	86.7
Secondary education / Vocational certificate	7	23.3	2	6.7
Higher vocational certificate / Diploma	1	3.3	2	6.7
Bachelor's degree or higher	1	3.3	0	0
5. Smoking status				
Smoker	10	33.3	11	36.7
Non-smoker	20	66.7	19	63.3
6. Alcohol consumption				
Yes	11	36.7	13	43.3
No	19	63.3	17	56.7
7. Roles and responsibilities in agricultural activities **(multiple responses allowed)**				
Chemical spraying	26	86.7	29	96.7

Chemical mixing	22	73.3	23	76.7
Irrigation (watering or water management)	9	30.0	8	26.7
Harvesting	5	16.7	6	20.0
Seed planting (sowing)	7	23.3	8	26.7
Soil cultivation (tilling)	10	33.3	8	26.7
Pruning and product packaging	1	3.3	3	10.0
8. Sources of information on pesticides (multiple responses allowed)				
Neighbors	9	30.0	13	43.3
Chemical vendors	26	86.7	27	90.0
Government officials	3	10.0	4	13.3
9. Channels for receiving information via media and social media (multiple responses allowed)				
Television	22	73.3	27	90.0
Radio	24	80.0	29	96.7
Leaflets	19	63.3	21	70.0
Posters	9	30.0	5	16.7
Internet	12	40.0	12	40.0
10.1 Duration of pesticide use				
1–10 years	12	40.0	6	20.0
11–20 years	9	30.0	14	46.7
21–30 years	8	26.7	8	26.7
31–40 years	1	3.3	2	6.7
10.2 Agricultural land area				
1.0 – 1.6 hectares	15	50.0	13	43.3
1.7 - 3.3 hectares	8	26.7	9	30.0
3.4 – 4.8 hectares	5	16.7	4	13.3
4.9 – 6.4 hectares	1	3.3	3	10.0
More than 6.5 hectares	1	3.3	1	3.3
11. Household expenditure on pesticides in the past 6 months				
Less than 410 USD	17	56.7	12	40.0
Between 411 – 619 USD	13	43.3	14	46.7
Between 620 – 928 USD	0	0.0	4	13.3
More than 929 USD	0	0.0	0	0.0
12. Reasons for using pesticides in agricultural practices (multiple responses allowed)				
To control weeds	30	100.0	29	96.7
To control insects and plant diseases	30	100.0	28	93.3
To enhance crop productivity	23	76.7	20	66.7
Based on recommendations from pesticide vendors	14	46.7	12	40.0
Influenced by information from advertisements through various media	6	20.0	7	23.3
Based on recommendations from fellow farmers	12	40.0	14	46.7
13. Sources of consultation or advice on plant diseases or pests in the past 6 months (multiple responses allowed)				
Agricultural officers/academics	17	56.7	20	66.7
Pesticide vendors	25	83.3	21	70.0
Fellow farmers	17	56.7	11	36.7
14. Experience of health problems related to pesticide use in the past 6 months				
Yes (experienced health problems)	2	6.7	2	6.7

No (did not experience health problems)	28	93.3	28	93.3
15. Methods of disposal of pesticide containers in the past 6 months (multiple responses allowed)				
Burning	17	56.6	20	66.7
Collecting and selling to recycling buyers	22	73.3	18	60.0
Disposing of it indiscriminately in agricultural fields without proper treatment	20	66.7	22	73.3
Placing in garbage bins for municipal collection and disposal	5	16.7	6	20.0

Table 10 presents the mean scores of farmers' knowledge regarding health and safety protection from pesticide use in the experimental group before the intervention, after 8 weeks, and after 12 weeks, classified by operational phase. The findings demonstrate a clear and progressive improvement in knowledge scores across all domains following the intervention's implementation.

In the pre-application phase, the mean knowledge score increased from a moderate level at baseline (mean = 0.62) to a higher moderate level after 8 weeks (mean = 0.75), and further improved to a high level at the 12-week follow-up (mean = 0.83). A similar pattern was observed during the application phase, with the mean score increasing from 0.62 at baseline to 0.75 after 8 weeks, peaking at 0.85 at 12 weeks.

For the post-application phase, the mean score improved from 0.64 before the intervention to 0.82 after 8 weeks and further increased to 0.87 at 12 weeks, indicating sustained knowledge enhancement over time. Likewise, health impact awareness showed continuous improvement, rising from 0.64 at baseline to 0.71 after 8 weeks and reaching a high level of 0.78 at the 12-week assessment.

Overall, the mean knowledge score increased from a moderate level before the intervention (Mean = 0.63) to 0.76 after 8 weeks and to 0.84 at 12 weeks. These findings suggest that the intervention was effective in improving farmers' knowledge of pesticide-related health and safety protection, with the most substantial gains observed at the 12-week follow-up.

Table 10: Knowledge of health and safety protection from pesticide use among farmers in the experimental group before and after the implementation of the intervention at 8 and 12 weeks, classified by phase (n = 30).

Knowledge of health and safety protection among the experimental group	**Before intervention**		**After intervention (8 Weeks)**		**After intervention (12 Weeks)**	
	Mean	Interpretation	Mean	Interpretation	Mean	Interpretation
Pre-application phase	.62	Moderate	.75	Moderate	.83*	High
During the application phase	.62	Moderate	.75	Moderate	.85*	High
Post-application phase	.64	Moderate	.82	Moderate	.87*	High
Health impact awareness	.64	Moderate	.71	Moderate	.78*	High
Total mean	.63	Moderate	.76	Moderate	.84*	High

**** Statistically significant at the 0.05 level.***

Table 11 presents the pairwise comparisons of mean knowledge scores related to health and safety protection from pesticide use among farmers in the experimental group, analyzed using the Bonferroni post hoc test across three measurement periods: before the intervention, immediately after 8 weeks of intervention, and at the 12-week follow-up. The results revealed that the mean knowledge score increased significantly from baseline (mean = 0.669) to immediately after the intervention (mean = 0.761, $p < .05$), indicating that the intervention produced an immediate positive effect on farmers' knowledge regarding safe pesticide use. A further significant increase was observed between the baseline assessment and the 12-week follow-up, with the mean score rising from 0.669 to 0.843 ($p < .05$). This finding suggests not only immediate knowledge gain but also sustained retention and continued improvement over time. In addition, the comparison between the 8-week post-intervention assessment and the 12-week follow-up demonstrated a statistically significant improvement, with the mean score increasing from 0.761 to 0.843 ($p < .05$). This indicates that farmers continued to consolidate and apply the knowledge they had acquired even after completing the intervention activities.

Table 11: Pairwise comparisons of mean scores for knowledge of health and safety protection from pesticide use among the experimental group before the intervention, after 8 weeks of intervention, and at 12-week follow-up, using the Bonferroni method (n = 30).

Knowledge of health and safety protection from pesticide use among farmers	Mean	p-value
Before the intervention	0.669	P<.05
Immediately after the intervention	0.761*	
Immediately before the intervention	0.669	P<.05
During the follow-up period	0.843*	
Immediately after the intervention	0.761	P<.05
During the follow-up period	0.843*	

*** Statistically significant at the 0.05 level***

Part 2: Results of the analysis of health and safety protective behaviors related to chemical use among farmers in the experimental group

Table 12 presents the comparison of mean scores for health and safety protective behaviors related to pesticide use among farmers in the experimental group before the intervention, after 8 weeks, and after 12 weeks, classified by behavioral domain. The findings demonstrate statistically significant improvements across all domains following the intervention ($p < .05$).

In the pre-application phase, the mean behavioral score increased from a low level before the intervention (Mean = 1.50) to a moderate level after 8 weeks (Mean = 2.03), and further to 2.24 at the 12-week follow-up. This suggests marked improvement in farmers' preparation practices prior to pesticide use.

For behaviors in the during-application phase, the mean score improved from 1.55 at baseline to 2.20 after 8 weeks and remained slightly higher at 2.21 after 12 weeks. Although the level remained within the moderate range, the findings indicate sustained improvement in protective practices during pesticide application.

Similarly, in the post-application phase, the mean score increased from 1.56 before the intervention to 2.10 after 8 weeks and to 2.36 at the 12-week follow-up, reflecting continued improvement in safe post-use handling and disposal behaviors.

Regarding health hazard–related behaviors, the mean score improved from a moderate level at baseline (mean = 2.35) to a high level after 8 weeks (mean = 2.45), and further increased to 2.62 at 12 weeks. This indicates substantial improvement in farmers' behavioral responses to health risks and early symptoms associated with pesticide exposure.

Overall, the total mean behavioral score increased significantly from 1.65 before the intervention to 2.15 after 8 weeks and 2.32 after 12 weeks ($p < .05$). These findings suggest that the intervention was effective in improving farmers' protective behaviors related to pesticide use, with improvements being maintained and further strengthened over time.

Table 12: Comparison of mean scores by domain of health and safety protective behaviors related to pesticide use among farmers before and after the intervention in the experimental group (n = 30).

Behavior	Time period	Mean	Level	P value
1. Pre-application phase	Before the intervention	1.50	Low	P<.05
	After 8 weeks of intervention	2.03*	Moderate	
	After 12 weeks of intervention	2.24*	Moderate	
2. During-application phase	Before the intervention	1.55	Moderate	P<.05
	After 8 weeks of intervention	2.20*	Moderate	
	After 12 weeks of intervention	2.21*	Moderate	
3. Post-application phase	Before the intervention	1.56	Moderate	P<.05
	After 8 weeks of intervention	2.10*	Moderate	
	After 12 weeks of intervention	2.36*	Moderate	
4. Health hazards	Before the intervention	2.35	Moderate	P<.05

	After 8 weeks of intervention	2.45	High	
	After 12 weeks of intervention	2.62*	High	
Total mean	Before the intervention	1.65	Moderate	P<.05
	After 8 weeks of intervention	2.15*	Moderate	
	After 12 weeks of intervention	2.32*	Moderate	

**** Statistically significant at the 0.05 level.***

Table 13 presents the Bonferroni pairwise comparisons of mean scores for health and safety protective behaviors related to pesticide use among farmers in the experimental group across three assessment periods: before the intervention, immediately after 8 weeks of intervention, and at the 12-week follow-up.

The findings showed that the mean behavioral score increased significantly from baseline (mean = 1.66) to immediately after the intervention (mean = 2.16, $p < .05$), indicating that the intervention had an immediate positive effect on farmers' protective behaviors related to pesticide use.

A further statistically significant improvement was observed between the baseline and the 12-week follow-up period, with the mean score increasing from 1.66 to 2.36 ($p < .05$). This substantial increase suggests that the intervention not only improved immediate behavioral practices but also contributed to the sustained maintenance of safer behaviors over time.

In addition, the comparison between the 8-week post-intervention assessment and the 12-week follow-up also revealed a statistically significant increase, from 2.16 to 2.33 ($p < .05$). This indicates that behavioral improvements continued to develop even after the formal intervention period, reflecting ongoing adoption and reinforcement of safe pesticide-use practices among farmers.

Overall, the Bonferroni post hoc analysis confirms that the intervention was effective in producing significant short-term and long-term improvements in health and safety protective behaviors related to pesticide use among farmers in the experimental group.

Table 13: Pairwise comparisons of mean scores of health and safety protective behaviors related to chemical use among farmers, classified by domain, before the intervention, after 8 weeks, and after 12 weeks of the intervention in the experimental group, using the Bonferroni method (n = 30).

Health and safety protective behaviors related to pesticide use among farmers	**Mean**	**p-value**
Before the intervention	1.66	P<.05
Immediately after the intervention	2.16*	
Before the intervention	1.66	P<.05
follow-up period	2.32*	
Immediately after the intervention	2.16	P<.05
follow-up period	2.32*	

**** Statistically significant at the .05 level.***

Part 3: Results of the analysis of knowledge regarding health and safety protection from chemical use among farmers in the control group

Part 5: Comparative Analysis of Knowledge and Behaviors Related to Health and Safety Protection from Chemical Use among Farmers between the Experimental and Control Groups

Table 14 presents the comparison of baseline knowledge scores regarding health and safety protection from pesticide use between the experimental and control groups, analyzed using an independent t-test. The findings indicate that no statistically significant differences were observed between the two groups across any knowledge domains prior to the intervention ($p > .05$).

In the pre-application phase, the experimental group had a mean score of 0.65, while the control group had a comparable mean score of 0.64, both classified as moderate ($p = .370$). Similarly, during the application phase, the mean scores were 0.74 for the experimental group and 0.69 for the control group, both within the moderate range, with no statistically significant difference detected ($p = .072$).

For the post-application phase, the mean scores were nearly identical between the experimental group (0.63) and the control group (0.64) ($p = .469$). A similar pattern was found for health impact awareness, with both groups reporting mean scores of 0.63–0.64, also classified as moderate (p = .439).

Overall, the total mean knowledge score did not differ significantly between the experimental group (0.66) and the control group (0.63) prior to the intervention (p = .093). These findings suggest that the two groups were comparable at baseline in their knowledge of health and safety protection from pesticide use, thereby supporting the internal validity of subsequent intervention comparisons.

Table 14: Knowledge of health and safety protection from pesticide use among farmers before the intervention, comparing the experimental and control groups using an independent t-test (n = 60).

Knowledge of health and safety protection before the intervention	Experimental group		Control group		P value
	Mean	**Level**	Mean	**Level**	
Pre-application phase	.65	Moderate	.64	Moderate	.37
During-application phase	.74	Moderate	.69	Moderate	.07
Post-application phase	.63	Moderate	.64	Moderate	.47
Health impacts	.63	Moderate	.64	Moderate	.44
Total mean	.66	Moderate	.63	Moderate	.09

**** Statistically significant at the 0.05 level.***

Table 15 presents the comparison of baseline health and safety protective behaviors related to pesticide use between the experimental and control groups, analyzed using an independent t-test. The results indicate that no statistically significant differences were found between the two groups across all behavioral domains before the intervention ($p > .05$).

In the pre-application phase, both groups demonstrated similarly low levels of protective behavior, with mean scores of 1.50 in the experimental group and 1.51 in the control group (p = .346). During the application phase, the mean scores were 1.55 and 1.57, respectively, with both groups classified as moderate, and no statistically significant difference was observed (p = .363).

A similar pattern was identified in the post-application phase, where the experimental group had a mean score of 1.56, compared with 1.61 in the control group, both remaining within the moderate range (p = .224). Regarding health impact–related behaviors, the experimental and control groups reported comparable mean scores of 2.35 and 2.32, respectively, also at the moderate level (p = .433).

Overall, the total mean behavioral scores were 1.65 for the experimental group and 1.68 for the control group, with no statistically significant difference detected (p = .272). These findings confirm that the two groups were behaviorally equivalent at baseline, thereby providing a robust basis for evaluating the intervention's effects in subsequent analyses.

Table 15: Comparison of health and safety protective behaviors related to pesticide use among farmers before the intervention between the experimental and control groups, using an independent t-test (n = 60).

Health and safety protective behaviors before the intervention	Experimental group (n=30)		Control group (n=30)		P-value
	Mean	**Level**	Mean	**Level**	
Pre-application phase	1.50	Low	1.51	Low	.346
During-application phase	1.55	Moderate	1.57	Moderate	.363
Post-application phase	1.56	Moderate	1.61	Moderate	.224
Health impacts	2.35	Moderate	2.32	Moderate	.433
Overall	1.65	Moderate	1.68	Moderate	.272

**** Statistically significant at the 0.05 level.***

Table 16 compares the mean knowledge scores regarding health and safety protection from pesticide use between the experimental and control groups across three assessment periods: before the intervention, after 8 weeks, and after 12 weeks. The findings demonstrate statistically significant between-group differences over time across all domains ($p < .05$), indicating the intervention's effectiveness in improving farmers' knowledge in the experimental group.

In the pre-application phase, the experimental group’s mean score increased progressively from 0.62 at baseline to 0.75 after 8 weeks and 0.83 after 12 weeks, whereas the control group remained relatively stable (0.64, 0.65, and 0.64, respectively). Similar improvements were observed during the application phase, where the experimental group improved from 0.62 to 0.75 and 0.85, while the control group showed no meaningful change (0.69, 0.62, and 0.62).

In the post-application phase, the experimental group showed a marked increase from 0.64 before the intervention to 0.82 after 8 weeks and 0.87 after 12 weeks, whereas the control group remained nearly unchanged (0.64, 0.67, and 0.67). Likewise, in the domain of health hazard awareness, the experimental group improved from 0.64 at baseline to 0.71 and 0.78, whereas the control group maintained the same mean score (0.64) across all time points.

Overall, the mean knowledge score in the experimental group increased substantially from 0.63 before the intervention to 0.76 after 8 weeks and 0.84

after 12 weeks, whereas the control group remained at 0.63 throughout the study period. These findings provide strong evidence that the intervention significantly enhanced farmers' knowledge regarding health and safety protection from pesticide use, with sustained improvements observed through the 12-week follow-up.

Table 16: Comparison of mean scores of knowledges regarding health and safety protection from chemical use across three phases and health hazards between the control and experimental groups after 8 and 12 weeks of the intervention (n = 60).

Time period	Group	Before the intervention	After 8 weeks of intervention	After 12 weeks of intervention	P value
		Mean	Mean	Mean	
1. Pre-application phase	Experimental group	.62	.75	.83*	P<.05
	Control group	.64	.65	.64	
2. During-application phase	Experimental group	.62	.75	.85*	P<.05
	Control group	.69	.62	.62	
3. Post-application phase	Experimental group	.64	.82	.87*	P<.05
	Control group	.64	.67	.67	
4. Health hazards	Experimental group	.64	.71	.78*	P<.05
	Control group	.64	.64	.64	
Overall	Experimental group	.63	.76	.84*	P<.05
	Control group	.63	.63	.63	

* Statistically significant at the 0.05 level

Table 17 presents the comparison of mean scores for health and safety protective behaviors related to pesticide use between the experimental and control groups across three assessment periods: before the intervention, after 8 weeks, and after 12 weeks. The findings demonstrate a clear and sustained improvement in protective behaviors among farmers in the experimental group, whereas the control group showed minimal change across all domains.

In the pre-application phase, the experimental group's mean behavioral score increased substantially from 1.50 at baseline to 2.03 after 8 weeks and 2.24 after 12 weeks, while the control group remained essentially unchanged (1.50, 1.51, and 1.50, respectively). A similar trend was observed during the application phase, where the experimental group improved from 1.55 before the intervention to 2.20 after 8 weeks and 2.21 after 12 weeks, whereas the control group showed only marginal variation (1.55, 1.56, and 1.58).

For the post-application phase, the experimental group showed a marked increase from 1.56 at baseline to 2.10 after 8 weeks and 2.36 after 12 weeks, whereas the control group remained stable at approximately 1.56–1.58 throughout the study period. In terms of health hazard–related behaviors, the experimental group improved from 2.35 before the intervention to 2.45 after 8 weeks and 2.62 after 12 weeks, while the control group exhibited only slight increases (2.35, 2.36, and 2.43).

Overall, the total mean behavioral score in the experimental group increased from 1.65 at baseline to 2.15 after 8 weeks and 2.32 after 12 weeks, whereas the control group remained virtually unchanged (1.65, 1.65, and 1.64). These findings indicate that the intervention was effective in significantly improving farmers' protective health and safety behaviors related to pesticide use, with these improvements maintained through the 12-week follow-up period.

Table 17: Comparison of mean scores of health and safety protective behaviors related to chemical use across three phases and health hazards between the control and experimental groups after 8 and 12 weeks of the intervention (n = 60).

Time period	Group	Before the intervention	After 8 weeks of intervention	After 12 weeks of intervention
		Mean	Mean	Mean
1. Pre-application phase	Experimental group	1.50	2.03*	2.24*
	Control group	1.50	1.51	1.50
2. During-application phase	Experimental group	1.55	2.20*	2.21*
	Control group	1.55	1.56	1.58
3. Post-application phase	Experimental group	1.56	2.10*	2.36*
	Control group	1.56	1.57	1.58
4. Health hazards	Experimental group	2.35	2.45	2.62*

	Control group	2.35	2.36	2.43
Overall mean	Experimental group	1.65	2.15	2.32
	Control group	1.65	1.65	1.64

**** Statistically significant at the 0.05 level.***

Part 6: Results of blood testing for cholinesterase levels among farmers in the experimental and control groups before and after the intervention

Table 18 presents serum cholinesterase blood test results among farmers in the control and experimental groups at baseline and at the 12-week follow-up. The findings indicate markedly different trends between the two groups over time.

In the control group, only minimal changes in serum cholinesterase status were observed across the study period. The proportion of farmers classified as unsafe increased slightly from 10.0% (n = 3) at baseline to 13.3% (n = 4) after 12 weeks. Similarly, the at-risk category showed only a marginal decrease from 36.7% (n = 11) to 33.3% (n = 10). Small increases were noted in the safe category, from 30.0% (n = 9) to 33.3% (n = 10), while the proportion classified as normal decreased slightly from 23.3% (n = 7) to 20.0% (n = 6). Collectively, these findings suggest only minor fluctuations, with no evidence of meaningful biological improvement in the control group.

In contrast, the experimental group demonstrated substantial improvement in serum cholinesterase levels following the intervention. At baseline, 10.0% (n = 3) of participants were categorized as unsafe, which decreased markedly to 3.3% (n = 1) at the 12-week follow-up. The proportion of farmers in the at-risk category also declined considerably, from 40.0% (n = 12) to 10.0% (n = 3). Conversely, the percentage of participants classified as safe increased markedly from 23.3% (n = 7) at baseline to 53.4% (n = 16) after the intervention. A further improvement was observed in the normal category, which increased from 26.7% (n = 8) to 33.3% (n = 10).

Overall, these findings provide strong evidence that the intervention was associated with clinically meaningful improvements in biological markers of pesticide exposure, as reflected by the substantial shift from unsafe and at-risk categories toward safe and normal serum cholinesterase levels in the experimental group.

Table 18: Blood test results for serum cholinesterase levels among farmers in the control and experimental groups before the intervention and after 12 weeks.

Blood test results	Control group				Experimental group			
	Before		After		Before		After	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Unsafe	3	10.0	4	13.3	3	10.0	1	3.3
At risk	11	36.7	10	33.3	12	40.0	3	10.0
Safe	9	30.0	10	33.3	7	23.3	16	53.4
Normal	7	23.3	6	20.0	8	26.7	10	33.3
Total	30	100.0	30	100.0	30	100.0	30	100.0

Table 19 compares the serum cholinesterase blood test results between the control and experimental groups prior to the intervention. The findings showed that the proportion of farmers classified as unsafe and at risk was comparable across the two groups, at 46.7% (n = 14) in the control group and 50.0% (n = 15) in the experimental group. Likewise, the proportions of participants classified as safe and normal were similar, at 53.3% (n = 16) in the control group and 50.0% (n = 15) in the experimental group.

The chi-square analysis indicated no statistically significant difference in serum cholinesterase levels between the control and experimental groups at baseline (χ^2 = 0.360, df = 3, p = .947). These findings suggest that both groups had comparable biological risk profiles prior to the intervention, thereby supporting the study groups' baseline equivalence.

Table 19: Comparison of blood test results for serum cholinesterase levels among farmers between the experimental and control groups before the intervention.

Blood test results	Control group		Experimental group		Statistical analysis
	Number	Percentage	Number	Percentage	
Unsafe & at risk	14	46.7	15	50.0	χ^2=.360 Df = 3 P-value =.947
Safe & normal	16	53.3	15	50.0	
Total	30	100.0	30	100.0	

**** Statistically significant at the 0.05 level.***

Table 20 compares the serum cholinesterase blood test results between the control and experimental groups after the intervention. The findings revealed a clear difference in biological safety status between the two groups. In the control group, nearly half of the farmers (46.6%, n = 14) remained in the unsafe and at-risk categories. In contrast, the corresponding proportion in the experimental group was substantially lower at 13.4% (n = 4).

Conversely, the proportion of farmers classified as safe and normal was considerably higher in the experimental group (86.6%, n = 26) than in the control group (53.4%, n = 16). These findings indicate a marked improvement in serum cholinesterase levels among participants who received the intervention.

The chi-square test demonstrated a statistically significant difference between the two groups following the intervention ($\chi^2 = 7.954$, df = 3, p = .047), suggesting that the intervention was effective in improving biological indicators of pesticide exposure among farmers.

Overall, the results provide strong objective evidence that the community-participatory intervention model contributed to reducing pesticide-related physiological risk and enhancing farmers' health and safety outcomes.

Table 20: Comparison of blood test results for serum cholinesterase levels among farmers between the experimental and control groups after the intervention.

Blood test results	Control group		Experimental group		
	Number	Percentage	Number	Percentage	
Unsafe & At risk	14	46.6	4	13.4	χ^2=7.954 Df = 3 P-value=.047*
Safe & Normal	16	53.4	26	86.6	
Total	30	100.0	30	100.0	

**** Statistically significant at the 0.05 level.***

Table 21 presents the mean satisfaction scores regarding participation in activities based on the community-participatory model for health and safety protection from pesticide use among farmers. Overall, participant satisfaction with the intervention activities was rated highest (mean = 4.28), indicating a highly favorable perception of the developed model.

Among the individual dimensions, the highest mean score was observed for the item indicating that farmers could use pesticides safely (mean = 4.54), followed by overall satisfaction with the activities (mean = 4.32). Several other aspects were also rated at the highest level, including the clarity of problem identification and model development approaches (mean = 4.25), increased knowledge and understanding of pesticide use (mean = 4.26), improved preventive behaviors related to health and safety impacts (mean = 4.26), the applicability of the model in daily life (mean = 4.26), and the appropriateness of the model to the agricultural way of life (mean = 4.26).

The only dimension rated slightly lower, though still at a high level, was the perception that farmers could apply the model to solve problems and mitigate health impacts (mean = 4.20). Overall, these findings indicate that the intervention model was highly acceptable, contextually relevant, and perceived as practical for promoting safe pesticide use among farmers.

Table 21: Mean and standard deviation of satisfaction with participation in activities based on the community-participatory model for health and safety protection from pesticide use (n = 30).

Satisfaction	Mean	Interpretation
1. Farmers are able to use pesticides safely.	4.54	Highest
2. Overall satisfaction with the activities.	4.32	Highest
3. Farmers have gained increased knowledge and understanding of pesticide use.	4.26	Highest
4. Farmers demonstrate improved behaviors in preventing health and safety impacts.	4.26	Highest
5. The developed model can be applied by farmers in their daily lives.	4.26	Highest
6. The developed model is appropriate for the agricultural way of life.	4.26	Highest
7. The problem issues and approaches applied in the model development are clearly defined.	4.25	Highest
8. The activity implementation process of the developed model is appropriate for problem-solving.	4.23	Highest
9. Farmers have improved knowledge and understanding regarding pesticides.	4.23	Highest
7. The developed model is appropriate for the agricultural way of life.	4.26	Highest
Total	4.28	Highest

4.3. DISCUSSION

The researcher outlined the principal findings and analyzed the results in accordance with the research methodologies as follows:

1. Closing the Knowledge–Practice Gap

A key finding from Phase 1 was the persistence of a substantial knowledge–practice gap among farmers. Although the majority of participants (77.2%) demonstrated a high level of self-protection knowledge, their actual self-protective practices remained only at a moderate level, with several inappropriate behaviors still evident, particularly during the pre-application and post-application stages of pesticide use. The discrepancy underscores an important occupational health challenge: knowledge acquisition alone does not necessarily translate into safe behavioral execution in real-world agricultural settings. Similar international evidence has consistently shown that high knowledge scores may coexist with suboptimal pesticide safety practices, particularly regarding PPE use, label compliance, and disposal procedures (Istriningsih et al., 2022; Meunier et al., 2024).

The present finding reinforces the growing consensus that knowledge dissemination as a standalone intervention strategy is insufficient to produce sustained behavioral change among farmers. In practice, farmers' decision-making is embedded within a broader ecology of economic constraints, production-risk concerns, labor limitations, and time-sensitive farming routines, all of which may override occupational safety recommendations. Under such circumstances, immediate crop protection and household income security are often prioritized over adherence to protective measures, especially when these measures are perceived as inconvenient, costly, or disruptive to workflow efficiency. Behavioral science evidence suggests that these decisions are rarely driven by cognition alone, but instead emerge from the interaction of individual beliefs, social norms, and external market pressures (Meunier et al., 2024).

From a broader international policy perspective, the pattern aligns with the transition from information-deficient models toward implementation-oriented risk governance frameworks, which recognize that knowledge must be supported by enabling environments to become actionable. In Thailand, where farmers frequently rely on pesticide retailers and informal peer networks as trusted sources of operational advice, education-only programs delivered through conventional public-sector channels may have limited reach and behavioral impact. Therefore, policy strategies should move beyond one-way information delivery and instead incorporate economically feasible protective options, context-sensitive behavioral nudges, locally trusted reinforcement networks, and stronger regulation of retailer-based risk communication. Such an approach is more likely to narrow the knowledge–practice gap while remaining compatible with the realities of Thai agricultural livelihoods.

At the systems level, these findings suggest that effective pesticide safety policy should be repositioned within a community-centered and implementation science framework, where behavioral supports are embedded into routine farming practices rather than treated as episodic health education campaigns. For Thailand, it may include integrating village health volunteers, local agricultural leaders, and pesticide vendors into a coordinated safety ecosystem, thereby translating formal knowledge into socially reinforced, economically realistic, and sustainable protective behavior.

4.3.1. The Power of the AIC Process and Community Participation

Another critical strength of the proposed model lies in the AIC process and the active participation of community stakeholders, which shifted the intervention away from a conventional top–down approach toward a community-driven decision-making mechanism. The model's success was not primarily attributable to externally imposed instructions, but rather to the collective engagement of 19–21 key stakeholders, ranging from community leaders and local farmers to pesticide retailers, who jointly identified problems, analyzed root causes, and co-developed feasible action plans. The collaborative process fostered a strong sense of shared ownership, collective responsibility, and local legitimacy, thereby enhancing the intervention's acceptability and sustainability.

The finding is highly consistent with international literature on high-level community participation, which emphasizes that sustainable behavioral and systems change is more likely to occur when communities move beyond passive receipt of services toward partnership, delegated power, and citizen control. Arnstein's ladder of participation conceptualizes the transition as a redistribution of power from external authorities to community members, enabling stakeholders to become active co-creators of their own development pathways rather than merely recipients of interventions (Kenny et al., 2013). In context, the AIC process functioned as a practical participatory platform that enabled stakeholders with diverse social roles and influence—including actors from the local agricultural market system—to negotiate priorities, align expectations, and generate locally relevant solutions. Such a process is particularly important in reducing pesticide risk, where farmers' behaviors are deeply embedded in social relationships, economic dependencies, and trusted local information networks. Therefore, the observed effectiveness of the model may be explained not only by improved knowledge exchange but also by the emergence of community ownership, social accountability, and empowered local governance, all of which are recognized as key drivers of sustainable community health interventions (Eyre & Gauld, 2003).

4.3.2. Integration of PMT with Real-Life Community Contexts

A major strength of the intervention was the contextualized integration of PMT into community-based experiential learning, particularly through Activity 3, "Silent Death from Chemicals," which incorporated local role models and individuals directly affected by pesticide-related illness as narrative messengers. This strategy appears to have strengthened the threat appraisal pathway of PMT, especially the constructs of perceived severity and perceived vulnerability, which are central determinants of protective motivation (Bazrafkan et al., 2022). Rather than relying solely on abstract epidemiological statistics or generalized health education, the use of lived experiences from members of the same community likely increased the personal relevance, emotional salience, and social credibility of pesticide-related risk, thereby making the threat more immediate and psychologically compelling.

The interpretation is strongly supported by international PMT literature, which consistently demonstrates that individuals are more likely to adopt protective behaviors when the threat is perceived as both serious and personally relevant, particularly when risk communication is delivered through vivid, experience-based narratives rather than impersonal information (Morrongiello & Corbett, 2011) In agricultural settings, PMT-based studies further show that perceived severity and perceived vulnerability significantly predict farmers' intentions to adopt protective and conservation behaviors, highlighting the importance of emotionally meaningful threat communication in translating awareness into action (Bazrafkan et al., 2022). In the present study, the progressive increase in awareness scores related to pesticide-associated health impacts provides empirical support for the mechanism, suggesting that community-based experiential communication may generate a stronger and more sustained behavioral shift than conventional didactic education alone.

Importantly, when health-risk messages are delivered by trusted individuals within the same sociocultural and occupational environment, participants are more likely to perceive the threat as authentic, locally relevant, and directly applicable to their own farming practices. The process reduces psychological distance and enhances motivation for self-protection, particularly in communities where social trust and peer credibility strongly shape behavioral norms. From a global policy perspective, the finding aligns with the movement toward people-centered risk communication frameworks, which emphasize locally grounded storytelling, community testimony, and culturally resonant messaging as key strategies for occupational health promotion in vulnerable agricultural populations (Morrongiello & Corbett, 2011).

In the Thai context, where pesticide safety practices are deeply embedded within local social relationships and agricultural routines, integrating PMT with community-based testimony and peer-led experiential learning offers a scalable and culturally congruent strategy for strengthening pesticide risk perception. Policy frameworks aimed at reducing pesticide-related harm among Thai farmers should therefore move beyond information transmission models and incorporate trusted local messengers, narrative-based threat communication, and village-level participatory learning platforms to sustain long-term protective behavior.

4.3.3. Biological Outcomes: Cholinesterase Enzyme Levels as Objective Validation of Intervention Success

One of the most compelling findings of the present study was a substantial reduction in the proportion of farmers classified as having unsafe or at-risk blood cholinesterase levels, from 46.7% at baseline to 13.3% after the intervention. The biological improvement provides the most robust empirical evidence that the self-reported behavioral modifications were not merely attitudinal or socially desirable responses, but rather represented actual reductions in pesticide exposure that translated into measurable physiological benefits.

From an occupational health perspective, the finding is particularly important because blood cholinesterase activity is a well-established biomarker of exposure to organophosphate and carbamate pesticides, directly reflecting the degree of neurotoxic burden experienced by agricultural workers. Therefore, the marked improvement in enzyme status strongly supports the interpretation that the community participatory model successfully altered real-world pesticide handling practices, including behaviors before, during, and after spraying, in ways that meaningfully reduced toxic absorption. International quasi-experimental evidence from Northern Thailand similarly demonstrated that participatory pesticide-risk reduction programs significantly improved protective behaviors while simultaneously increasing mean blood cholinesterase activity, confirming reduced internal contamination following behavioral intervention (Sawarng et al., 2021).

Importantly, the physiological outcome strengthens the causal argument that the intervention did more than improve knowledge, attitudes, or perceived risk. Instead, it indicates that the model was capable of reducing actual physiological risk, which represents the highest-level outcome target in occupational and environmental health research. Biological verification is particularly valuable because it minimizes the limitations of self-reported data and demonstrates that community-driven behavioral interventions can achieve clinically meaningful reductions in pesticide-related neurotoxic exposure. The interpretation is consistent with international biomonitoring studies showing that safer pesticide work practices are associated with significantly higher cholinesterase activity and lower symptom burden among exposed farmers (Jintana et al., 2009).

Taken together, the observed shift from unsafe to safe cholinesterase status provides strong evidence that the participatory community model did not simply change what farmers think, but fundamentally changed how they work and how their bodies respond to pesticide exposure, thereby fulfilling the ultimate goal of occupational health interventions: the reduction of tangible physiological harm.

4.3.4. Sustainability Mechanisms: Community Structures and Contextual Fit Beyond the Research Period

A critical mechanism underpinning the long-term sustainability of the intervention was the establishment of a community-level implementation committee, which served as a formal local governance structure for the continued coordination, monitoring, and reinforcement of safe pesticide practices beyond the active research period. This finding suggests that sustainability was not contingent upon the prolonged presence of the research team; rather, it emerged from the transfer of operational ownership to a locally embedded governance mechanism capable of maintaining implementation momentum within the community. In community-based occupational health interventions, such institutionalized local structures are particularly important because they formalize responsibility, ensure role continuity, and strengthen collective accountability among stakeholders, thereby enhancing the likelihood of sustained practice change (Hailemariam et al., 2019; Scheirer & Dearing, 2011).

The exceptionally high satisfaction score for practical applicability in daily life (mean = 4.28) further reinforces the model's sustainability potential. This finding indicates that participants perceived the intervention activities as highly relevant, feasible, and directly compatible with routine agricultural work practices. From an implementation science perspective, long-term sustainability is strongly influenced by the degree of contextual appropriateness and intervention fit, particularly the extent to which program components align with local work rhythms, seasonal labor demands, and pre-existing community norms (Hailemariam et al., 2019). By deliberately designing activities that were explicitly adapted to the agricultural way of life, the intervention minimized disruption to farmers' livelihoods and increased the likelihood of continued adoption after formal project completion.

This interpretation is consistent with international evidence suggesting that sustainable community health interventions are most successful when they combine local governance structures, stakeholder ownership, and contextual compatibility (Kenny et al., 2013). Rather than functioning as externally imposed short-term campaigns, interventions become self-sustaining when community actors are granted decision-making authority, operational flexibility, and socially legitimate roles, allowing program activities to be naturally embedded into everyday occupational and social routines. In this study, the interaction between institutionalized community support mechanisms and high lifestyle congruence appears to explain why the intervention remained operational as part of normal agricultural practice rather than ending with the formal research timeline.

From a broader global policy perspective, these findings align with the shift toward locally governed sustainability frameworks in public health and implementation science, which emphasize community ownership, structural embedding, and context-sensitive adaptation as prerequisites for enduring intervention effects (Scheirer & Dearing, 2011). In the Thai agricultural context, where farming activities are highly seasonal, socially networked, and deeply integrated into village life, sustainability is unlikely to be achieved through externally driven short-term training alone. Instead, long-term occupational health gains require village-level governance structures, routine reinforcement through community committees, and intervention designs that are congruent with local agricultural livelihoods.

Collectively, these findings suggest that the long-term impact of the intervention is most likely to be maintained through community-led continuity mechanisms, in which responsibility is embedded within local committees and daily agricultural routines. This transformation from a time-limited research activity into a durable, community-owned health practice offers a scalable policy model for strengthening pesticide safety and occupational health among farming populations across Thailand and comparable low- and middle-income agricultural settings. The sustainability of the model appears to stem not from prolonged researcher presence but from the establishment of locally governed community structures and the deliberate alignment of intervention activities with the agricultural way of life, enabling the program to persist as part of routine farming practice beyond the formal research period.

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5. CONCLUSION AND POLICY IMPLICATIONS

The present study provides robust evidence across three sequential phases, demonstrating the effectiveness of a community-participatory model for farmers' self-protection against pesticides.

In Phase 1 (baseline situational analysis), findings from 276 farmers revealed a substantial knowledge–practice discrepancy. Although the majority of participants (77.2%) demonstrated a high level of self-protection knowledge, their actual preventive practices remained only at a moderate level, particularly during the pre-spraying stage, where several unsafe behaviors were frequently reported. Common inappropriate practices included mixing multiple pesticides in a single application and failing to wear protective boots, thereby increasing the risk of dermal absorption. Importantly, the predominant source of information was pesticide retail shops (81.6%), while access to formal guidance from governmental health and agricultural agencies remained limited, highlighting a structural barrier in risk communication.

In Phase 2 (model development), the research team integrated the AIC participatory process with PMT to co-develop a contextually grounded intervention with 21 local stakeholders. The resulting model emphasized community co-ownership and experiential learning, comprising three major activities: station-based practical learning, hands-on skill development with real protective equipment, and testimony-based learning from local role models who had experienced pesticide-related health effects.

In Phase 3 (effectiveness evaluation), the quasi-experimental comparison between the intervention and control groups (30 participants per group) over 12 weeks demonstrated significant improvements in the intervention arm. Knowledge scores increased from a moderate level (0.63) to a high level (0.84), while self-protective behavior scores improved substantially from 1.65 to 2.32, with no comparable significant changes observed in the control group. Most notably, the proportion of farmers classified as having unsafe or at-risk blood cholinesterase levels markedly declined from 50.0% to 13.4% in the intervention group, whereas the control group remained at a persistently high-risk level of approximately 46.6%. The biological outcome provides strong objective confirmation that the reported behavioral changes translated into a meaningful reduction in physiological risk.

Additionally, participants reported the highest level of satisfaction (mean = 4.28), particularly regarding the model's compatibility with the agricultural way of life and its practical applicability to daily farming routines, indicating strong feasibility of implementation and long-term adoption potential.

In summary, the study demonstrates that a community participatory model can effectively narrow the knowledge–practice gap in pesticide safety behaviors. The observed success appears to be driven by the combination of experience-based risk awareness, locally trusted social learning, and institutional support through community-level implementation committees. From a policy perspective, the model has strong potential to serve as a scalable prototype for wider implementation across agricultural regions in Thailand, thereby contributing to the sustainable occupational health and well-being of Thai farmers.

Ethical Considerations: The study protocol was reviewed and approved by the Human Research Ethics Committee of the Suphan Buri Provincial Public Health Office (Approval No. 34/2568).

Declaration of competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence. The work reported in the paper.

CRediT authorship contribution statement: Phatpong Tangsasom: Conceptualization, Data curation, Formal analysis, Validation, Methodology, Investigation, Funding acquisition, Visualization, Sanhawat Chaiwong: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Acknowledgement: The authors sincerely acknowledge all community stakeholders, collaborating network partners, and pesticide-using farmers who kindly participated in the intervention activities and completed the research questionnaires. Their cooperation, commitment, and invaluable field-based perspectives greatly contributed to the rigor and successful implementation of this study.

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