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RESEARCH PAPER

Safety Behavior of Nepalese Strawberry Farmers as Reflected by the Protection Motivation Theory

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Abstract

In recent years, the trend of application of chemical pesticides in Nepal is increasing mainly in fruits. Misuse of pesticides can have deleterious effects on human health and the environment. Therefore, the major objective of this study was to assess the determinants of safe handling of pesticides among strawberry farmers from 5 villages comprising 2 wards of the Kakani Rural Municipality. The protection motivation theory (PMT) was utilized as the study's theoretical model. This study was based on data collected from different methods such as questionnaire survey, key informants' interviews, focus group discussions and field visits. Data were collected from 100 strawberry farmers via random sampling method. Structured equation modeling (SEM), Pearson's correlation coefficient and Mann Whitney *U* test were performed to study relationship between two variables and compare their means. The most commonly used pesticides for strawberry cultivation were imidacloprid, chlorpyrifos and mancozeb. Banned pesticides such as parathion-methyl were found to have been used in the area. Headache was the most common acute symptom reported by farmers. The results of the PMT variables among farmers showed that response efficacy (direct path coefficient, DPC = 0.30) showed a strong positive effect on the protective behavior of farmers. Likewise, fear of farmers (direct path coefficient, DPC = 0.24) had a strong positive effect on their reported acute symptoms. Socio-economic status like residence significantly affected the acute toxicity symptoms of farmers ($r = -0.22$; $p < 0.05$). Of all the constructs, fear and response efficacy were the primary factors influencing the protective behavior of strawberry farmers. Therefore, policymakers in Nepal can ensure the safe behavior of farmers through training and education primarily focusing on the potential dangers of chemical pesticides on humans and the environment.

Highlights

- The protection motivation theory was used to study farmers' safety behavior
- Parathion-methyl, the banned pesticide in Nepal is used in the study area
- Neonicotinoid and organophosphate insecticides were frequently used pesticides
- Headache was the most common acute symptom
- Fear and response efficacy must be targeted for increasing the safety behavior

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Introduction

Over the past few decades, chemical pesticides have increasingly become an integral part of modern agriculture. Farmers rely on chemical pesticides to control pests and diseases. These pesticides are often used to control vector-borne diseases such as malaria and dengue (van den Berg et al. 2021). Most pesticides are highly toxic in nature and kill insects indiscriminately; hence, the non-targeted organisms like earthworms and beneficial microbes are also adversely impacted due to their applications. In addition to this, overuse and inappropriate use of these chemicals have led to deterioration of human health and the environment (Jin et al. 2015). Issues related to pesticides adverse effects among farm-workers have been reduced by adopting good agricultural practices (GAP) and personal protective equipment (PPE) (Lari et al. 2023). However, past scholars working on occupational exposure to pesticides in low and middle-income nations have concluded that serious occupational exposure for farmers during pesticides application is still prevalent (Recena et al. 2006; Aniah et al. 2021). Furthermore, poor agricultural practices increased the levels of pesticide residues in strawberries from Kuwait (Jallow et al. 2017), Turkey (Kazar Soydan et al. 2021), Algeria (Mebdoua et al. 2017) and China (Qin et al. 2021). Consumers were also exposed to the risk of pesticides due to the similar agricultural practices in strawberry farming in Egypt (El-Sheikh et al. 2022). All these studies indicated, however, that farmers' adherence to protection behaviors are effective in minimizing their dietary and non-dietary exposure to pesticides.

Farmers' participation in protective behavior depends on various factors such as pesticide toxicity and hazard levels, beliefs, knowledge, and socio-economic barriers. Identifying the potential factors influencing adoption of protective behavior by farmers is necessary to provide insights into the hidden reality which motivates farmers' safe pesticide use behaviors. There are a number of studies assessing the knowledge and attitude related to safety behavior of farmers; however, studies based on a wide range of factors depending on established theories are limited, and there is a dearth of literature in the context of strawberry farmers in Nepal, in particular. Study based on a specific theory could improve our understanding of farmers' protective behavior. In this study, we used the protection motivation theory (PMT) to understand the determinants affecting the protective measures of farmers. Rogers (1975) introduced the concept of this theory, which later has been used as a framework to study protective behaviors (Su et al. 2022; Zhu et al. 2022; Li et al. 2023). Table S1 shows the worldwide application of PMT.

Protection motivation theory (PMT) is a human psychological risk assessment theory explaining the tendency of individuals to protect themselves when faced with a threat. This theory rests on 2 appraisals: threat and coping, thereby explaining health-protective behaviors. PMT is based on expected value theory that determines the likelihood of a person engaging in safety behavior. The theory says that in order to adopt safety measures, individuals need to perceive threats which will motivate them to develop coping strategies for changing their behavior. This model describes how people protect themselves and respond to perceived risks engaging in safety behavior. According to the PMT, perceived threats depend on different constructs, such as, severity, rewards, fear and vulnerability. Perceived severity involves the severity of potential harm whereas perceived vulnerability defines possibility of the harm. Similarly, coping mechanisms depend on response efficacy, response cost and self-efficacy. Response efficacy describes one's expectation for recommendations on minimizing the threat. Similarly, self-efficacy means one's ability to execute the proposed action plans.

Many scholars have used PMT to explain the nature of human behavior in decision making. Bazrafkan et al. (2022) applied this theory to study drivers affecting farmers' intention to follow measures related to conservation agriculture. They showed farmers' perceived severity, response cost and self-efficacy for not using such measures strongly influencing their fears regarding conservation agriculture. Farmers who had experienced such fear showed their intention to adopt measures for sustainable agriculture. The caveat here is the perception of knowledge related to risks. Uneducated farmers tended to engage in unsafe practices while spraying (Sharifzadeh et al. 2019; Bagheri et al. 2021). However, a micro-level factor influencing health risk tolerance ability of an individual is more dependent upon other situations such as optimistic bias (Inouye 2014). Enhancing the threat appraisal (such as vulnerability, severity, rewards, fear) has positive and negative effects on changing intentions and safety behavior (Sheeran et al. 2013). Although PMT has been used extensively in several risk related studies in the past (Gucer et al. 2003; Glendon and Walker 2013), to the best of our knowledge, it is the first study based on the theory to study holistically the safety behavior of farmers in the Nepalese context. Furthermore, this theory has been used elsewhere (Bazrafkan et al. 2022; Abdollahzadeh et al. 2024) to study farmers' practices related to Integrated Pest Management (IPM) and conservation agriculture.

Safety behavior and pesticide exposure are considered the most significant factors of the health consequences among farmers (Sharifzadeh et al. 2019). Studying farmers' behavior in pesticide use is crucial for preventing them from occupational exposure, minimizing environmental deterioration, and improving sustainability of chemical pest control methods. To minimize farmers' exposure to pesticides, studies related to pesticide use behavior among farmers is important. Previous studies conducted in Nepal have identified the experience of negative effects of chemical pesticides and their exposure (Bhandari et al. 2018; Paudel et al. 2024). To the best of our knowledge, no study to date has explored the perceptions of strawberry farmers in explaining their safety behavior in Nepal. However, studies concerning the protection behavior of farmers are scarce, particularly in developing countries like Nepal.

Materials and Methods

Conceptual framework of the PMT. The PMT framework is based on the following psychological and cognitive drivers of protection behavior. Figure 1 shows the conceptual framework used in this study. Data and variables used for the identification of each constructs of the PMT were presented in Table S2.

Response Efficacy. It refers to one's belief that the adaptive response will perform, that is, taking an action will be effective in self-protection. It can be expressed as the confidence of an individual that the action will effectively reduce or eliminate the perceived threat.

Self-efficacy. The term "self-efficacy" was first developed by psychologist Bandura (1977). Self-efficacy shows people's confidence in the ability to perform safety actions that affect their lives. It provides a basic foundation for motivation, well-being and personal achievement. It is the perceived capacity of an individual to perform the adaptive response.

Response cost. The term "response cost" was coined by Weiner (1962). It refers to penalties, fines, or monetary values associated with taking the adaptive coping response. The removal of fees (a positive reinforcement) contingent on the risky behavior may decrease the future likelihood of adoption of safety behavior.

Fear. This is a negative emotion showing a response that arises from the danger. The response may include signs of worry, discomfort and fright. Farmer's fear may occur in response to a certain symptom to which they associate a potential risk for themselves in future.

Perceived threat severity. This means how serious an individual believes that the threat would harm him or her. If farmers believe that they are subject to severe consequences due to their poor safety behavior, they are likely to adhere to protective measures during spray.

Perceived threat vulnerability. It refers to how personally susceptible an individual feels to the perceived threat. It reflects an individual's belief about the likelihood of incurring health consequences. Perceived vulnerability to illness can contribute in preventing unsafe behaviors (Yildirim et al. 2021).

Maladaptive rewards. It includes intrinsic and extrinsic benefits of neglecting a given protection behavior viz.

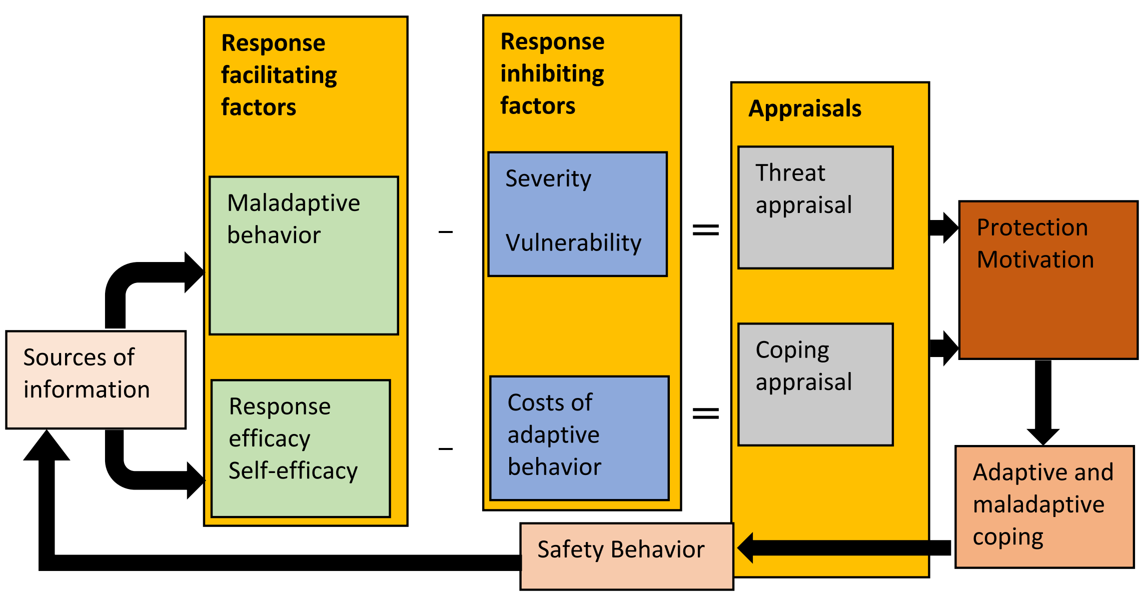

Fig. 1 Theoretical framework of the protection motivation theory applied to spraying behavior of strawberry farmers [Adapted from Ezati Rad et al. (2021)]

substance abuse. Such rewards may lead to attitudinal ambivalence in individuals when they process the fear appeal (Ng et al. 2021).

Adaptive behavior. The behavior of an individual in response to a fear that ultimately protects from the danger perceived in the fear appraisal. It enables an individual to cope with their changing environment with more success and less conflict.

Hypotheses

Specifically, based on the above cases and PMT, the 3 major hypotheses of the current study are as follows:

H1: Perceived severity significantly influences farmers' protection motivation toward safety behavior and symptom response.

H2: Fear significantly influences farmers' protection motivation toward safety behavior and symptom response.

H3: Response efficacy significantly influences farmers' protection motivation toward safety behavior and symptom response.

Modifying factors such as age and education affected vegetable farmers' safety behavior (Bhandari et al. 2018). Whether or not residence/location of farmers has influence with safety behavior and symptom response has not yet been investigated using the PMT theory. Therefore, the fourth hypothesis based on this scenario is formulated as follows:

H4: Residence significantly influences farmers' protection motivation toward safety behavior and symptom response.

Study Area

The study area is located in the Nuwakot district, a hilly region of Nepal. The Kakani Rural Municipality (27° 25.7′ N and 85° 24.6 ′ E) was purposively selected for this study considering the fact that the "HIME BERRY" in 2015 started commercial farming of strawberry for the first time in Nepal from this municipality. Figure 2 shows the map of study area. Kakani is located at elevation ranging from 1200 to 2200 m above mean sea level. The municipality has 8 wards, which are the smallest administrative units. The area and population of the municipality is 87.97 Km^2 and 24, 504, respectively. The municipality is dominated by a warm summer monsoon climate. The monthly average rainfall and temperature is about 447 mm and 28.35 °C, respectively. Rivers such as Kolpu khola and Bachhbichhe khola are the main source of water for strawberry irrigation. Besides strawberry, the other major crops cultivated in the municipality are paddy, millet, wheat, cabbage, cauliflower and radish. The study area has loamy soil with poor water holding capacity.

Research Design and Sampling Strategy

The population of this study comprises of about 325 farmers of Kakani cultivating strawberry. With the help of local agricultural departments, two wards: ward no. 2 and ward no. 5 were selected for survey. Survey locations were determined by random sampling technique. Based on the list of the strawberry farmers provided by the HIME BERRY, a major strawberry producer in the district, 100 farmers were randomly selected in the wards as survey respondents. The sample size was calculated based on 95% confidence level with a survey margin of error of 8%. The selected farmers from the aforementioned wards were the residents of different villages ranging from higher to lower elevations: Kaule, Hile Bitta, Basnetpauwa, Kakani Height, and Ghamailo Basti. In comparison to villages in ward no. 5, villages in ward no. 2 were warmer due to adiabatic heating. Farmers were included if they conducted pesticide spraying during their work in fields. A pilot survey was conducted with 15 farmers in the neighboring village-Kanchaman Tole. The pilot test survey data were not included in the main survey. Farmers purchased pesticides mainly from pesticide retailers situated in the major vegetable and fruit markets in Kathmandu. However, a few farmers mentioned that they also buy pesticides from local retailers in Nuwakot district. Therefore, pesticide retailers situated in the district were also considered in this study. To have a closer look on the global understanding of the PMT, we conducted a systematic search of literature using the following keyword combination:

(i) Pesticide AND protection motivation theory
(ii) Safety behavior AND protection motivation theory

Articles from Web of Science and Scopus were considered for literature search published from 2006 to 2023. The removal of common material resulted in a combined total of 35 papers. We used the following criteria for inclusion of the material.

(i) Peer reviewed scientific articles
(ii) Articles with a clear method such as statistical or modeling
(iii) Articles with a clearly mentioned sample size and method

With the aforementioned criteria, a total of 20 research articles were included for the review to understand the global application of the PMT (Table S1).

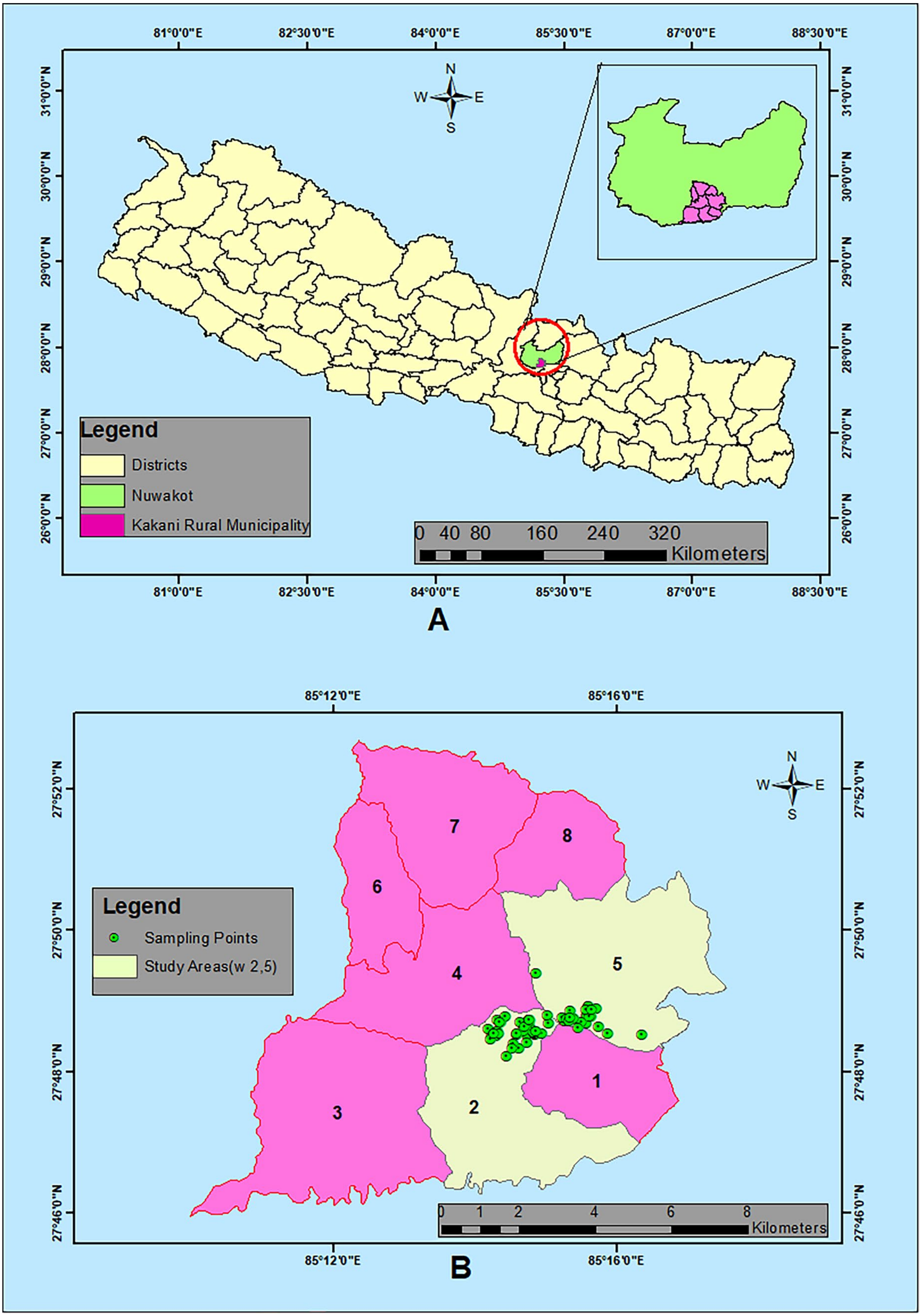

Fig. 2 Location map of Nuwakot district, Nepal (**A**) and study areas (ward no. 2 and 5) of Kakani Rural Municipality (**B**)

Survey Questionnaire

A standardized questionnaire constructed by the authors was designed after an extensive literature review and several field visits. The accuracy and content validity of the survey questionnaire was certified by a research committee of the Progressive Sustainable Developers Nepal who approved the constructs, indicators and questions that were designed based on the theory. The pilot survey ensured the clarity, appropriateness, adequacy and reliability of the research instrument (Gudmundsdottir and Brock-Utne 2010) by identifying and rectifying potential weakness in the survey (Malmqvist et al. 2019). Minor edits in the text were made in case of poor understanding of the survey questions prior to the implementation of the main survey. The questionnaire consisted of 6 constructs of the theory (39 items, Table S2) and 8 demographic characteristics of farmers.

The items of the theory were examined using Likert-type scales ranging from 1 to 5 (on a scale from 1 = completely disagree to 5 = completely agree). Furthermore, a mix of both positively and negatively phrased items were included to increase the reliability of the questionnaire (Bagheri et al. 2019a). Each interview was completed in approximately 30–40 min. The shortest recall method (24-h) was adopted in the process. Written consent was taken from the participating farmers and other stakeholders allowing respondents to terminate interviews or leave focus group discussions (FOGDs) and key informant interviews (KIIs) at any time. Four students studying agricultural science as a major at Tribhuvan University conducted the main survey. Additionally, 4 students studying Junior Technical Assistant (JTA) in the village who were knowledgeable of the local language ("*Tamang bhasa*") helped the interviewers. Before the actual survey, all students learned basic skills and the principal investigator (G. Bhandari) virtually provided research tips for conducting effective surveys. During a survey, the JTA translated the survey questions into the local language to facilitate understanding and response. Forty-four questions were included in the survey. Surveys were conducted verbally in the local language and the responses were written in English. All quantitative data and qualitative information were entered into Microsoft Excel spreadsheet and were double checked before analysis. In case an interview could not be completed in one go, the interviewer completed the interview at another convenient time with the permission from farmers. There were no refusals by farmers during the interview process.

Focus Group Discussions (FOGDs)

We designed a list of questions for the FOGDs. We conducted 2 FOGDs separately with the male and female farmers registered in the HIME BERRY, a major strawberry collection point in the study area. Male and female respondents were divided equally across groups to avoid the probability of gender mismatch. The HIME BERRY provided details of farmers in the municipality. Farmers were contacted randomly and their participation was entirely voluntary. Farmers responsible for pesticides handling, viz., accountable for purchasing and applying pesticides, were included in the discussion. Each FOGD lasted around 1–1.5 h. Questions were primarily focused on seeking information concerning: (i) integrated pest management (IPM), (ii) pesticide cocktails, (iii) toxic labels of pesticides, (iv) pesticide waste, (v) training on safe pesticide handling, (vi) waiting period, (vii) occupational exposure and safety, (viii) alternative practices to pesticides, (ix) strawberry markets, and (x) Government/institutional support for the farmers.

Key Informant Interviews (KIIs)

Key informants are individuals with specific knowledge about a society. People with specialized knowledge about pesticide use perspectives in strawberry farming were selected for the interview. We conducted one-to-one KIIs with a lead strawberry farmers and 2 staff members from Our Farms Nepal Pvt. Ltd., Kakani, Nuwakot. An agricultural extension officer from the Kakani Rural Municipality and 3 officers from National Agricultural Research Council (NARC), Lalitpur were interviewed. We also interviewed 3 senior horticulturist from Agricultural and Forestry University, Nepal. Interviews were conducted with 15 pesticide retailers in Kathmandu. Ten pesticide retailers from Nuwakot were also interviewed via phone and their information was recorded. Except Nuwakot, all interviews were conducted in a meeting room at the respective informants' offices and interview time was scheduled based on their convenience. A semi-structured interview framework considering key points was prepared in guidance with the multidisciplinary research team of PSD-Nepal. The checklist for interview was prepared, which included a pre-planned interview framework, consent form, and stationary items. The interview mainly focused on: (i) management of date expired pesticides, (ii) pesticide usage and strawberry markets, (iii) banned pesticides and their illegal use, (iii) pesticide handling and safety practices of retailers and farmers, (iv) integrated management of pests and diseases, (v) occupational exposure and health effects of pesticides, and (vi) capacity building programs focusing on farmer and retailer safety.

Field Visits

Four-day field trips to strawberry fields were conducted twice. Twenty-four farms were visited during the field visit. The aim of the visit was to acquire information on farmers' field and storage places of pesticides and containers for understanding their pesticide protection behaviors. Photographs of the different sites were taken and maintained along with notes. Farmers' list of pesticides and their reported health complaints (24-h reported acute symptoms related to pesticides exposure) were recorded during the field visit. Whenever feasible or applicable, farmers were asked to show the interviewer the pesticide packets and containers in order to avoid conflicting answers. Farmers' reported health consequences were based on their knowledge and experiences.

Research Ethics

Written consent was obtained from the respondents before conducting the key informant interviews, questionnaire survey, focus group discussions and field visits. Before conducting the activities, respondents were informed that their involvement in the study would be voluntary and their responses to the queries would be considered anonymously and confidentially. We made a commitment that outcomes of the current study and results would be used for research purposes only.

Data Analysis

The data from the survey were analyzed in IBM® SPSS® Statistics version 23 and Amos (7.0). A PCA analysis was performed to determine the relationship between the socioeconomic background of the farmers and their reported acute toxicity symptoms due to chemical pesticides. Normality of the data was tested using Kolmogorov–Smirnov test. A nonparametric test is appropriate in a case of non-normal distribution and small sample size. Therefore, the Mann Whitney U test was performed to compare outcomes between two wards (2 and 5 wards) of the municipality. The reliability of the model was tested using Cronbach's alpha (CA), composite reliability (CR), and goodness-of-fit (GoF) indices. GoF was calculated as alpha often underestimates the reliability while CR tends to overestimate it. As a result, the actual reliability of the model lies somewhere between the two measures. All indices were interpreted with caution. The alpha values > 0.7 signifies high reliability while the values ranging from 0.6 to 0.7 are deemed acceptable (Hair et al. 2014; Taber 2017). Overall fit of the model was tested with GoF index (Henseler and Sarstedt 2013). Three values of GoF i.e., 0.01, 0.25, and 0.35 present weak, moderate, and robust fit of a model, respectively (Wetzels et al. 2009). The structural equation modeling (SEM) was used to study the impact of independent factors of the study on the dependent factors. Before examining the model, the reliability of the model was tested with CA and CR, depicting control of measurement errors and internal consistency, respectively. Similarly, a path analysis was performed for SEM on different variables to examine the cause-effect relationship between the factors affecting the protection behavior of farmers. Such effect has been categorized into 3 groups such as minor effect (< 0.10), medium effect (0.10–0.19), and major effect (> 0.20) (Lockie et al. 2004). This study is based on these effects identifying the direct and indirect factors influencing strawberry-growing farmers' protection motivation. Additional key factors affecting the symptom response was performed as a supplement.

Results and Discussion

Demography

A majority of the farmers included in this study were illiterate. The characteristics of strawberry farmers from 2 wards of the municipality is shown in Table 1. Educated farmers have a willingness to participate in advice and training and make a greater use of information they get (Kilpatrick 2000). Overall, about half (45%) of the farmers were male. Both males and females showed low use of PPE and demonstrated poor safety behaviors, a finding similar to a past study conducted in Australian farm (Brumby et al. 2022). More than 85% of the farmers depended on agriculture and the rest had different sources of income. About 35% of the farmers were illiterate handling pesticides without proper instructions and PPE. The low PPE usage might be due different reasons such as cost, availability, discomfort, time and training. In this study, illiterate farmers were exposed to pesticides more than the literate farmers as they have a poor understanding of the harmful effects of pesticides on health and the environment (Rios-Gonzalez et al. 2013). Nearly 30% of the farmers were 26–35 years old. Farmers had different levels of knowledge and skills related to strawberry farming. Farmers from ward no. 2 had significantly greater farming experiences and higher land area for strawberry cultivation ($p = 0.013$ and 0.042, respectively). Cent percent of the farmers used plastic as a mulch. "Farmers' demand of plastic mulching is increasing every year", an agricultural extension agent stated in an interview. Farmers used low-density polyethylene (LDPE) black plastic sheet in fields mainly to prevent evapotranspiration and weeds. Plastic film mulching has contributed to the soil pollution abroad (Long et al. 2023). Interaction of microplastics and pesticides may lead to a decline in the soil microbial community, and ultimately agricultural productivity (Beriot et al. 2023). Most of the farmers ($> 90\%$) in the municipality were unaware of the

Table 1 Demography of strawberry farmers

Variables	Wards		P value
	Ward no. 2	Ward no. 5	
	Number of farmers (%)	Number of farmers (%)	
Gender			
Male	27	18	0.345
Female	38	17	
Main source of income			
Agriculture	56	33	0.275
Job	4	1	
Business	1	0	
Remittance	2	0	
Unskilled worker	2	1	
Age group			
25 and less	11	3	0.199
26–35	21	10	
36–45	17	10	
46–55	7	8	
56–65	7	1	
66–75	2	1	
76 and more	0	2	
Education			
Illiterate	26	10	0.286
Elementary	26	15	
Secondary	5	8	
High school	7	1	
College	1	1	
Experience of farming			
0–5	18	16	0.013*
6–10	13	9	
11–15	20	8	
16–20	4	1	
21 and more	10	1	
Number of family members			
0–5	47	24	0.637
6–10	18	10	
11 and more	0	1	
Area of strawberry production (Ropani)			
0–5	61	35	0.042*
6–10	3	0	
11 and more	1	0	
Monthly income (#NRs)			
0–25000	31	20	0.275
26,000–50000	28	14	
51,000–75000	2	0	
76,000 and more	4	1	

*Significant at $p < 0.05$; 1 Ropani = 0.05 ha; #1 US Dollar was approximately equal to 132 NRs in 2024

toxicity of such interactions. Increasing use of plastic mulching in the agriculture may alter soil microbial communities, resulting in an increased presence of pests and diseases.

Use of Pesticides in Strawberry Cultivation

Overall, 83% of the farmers used chemical pesticides. Neonicotinoid insecticides were commonly used. The most

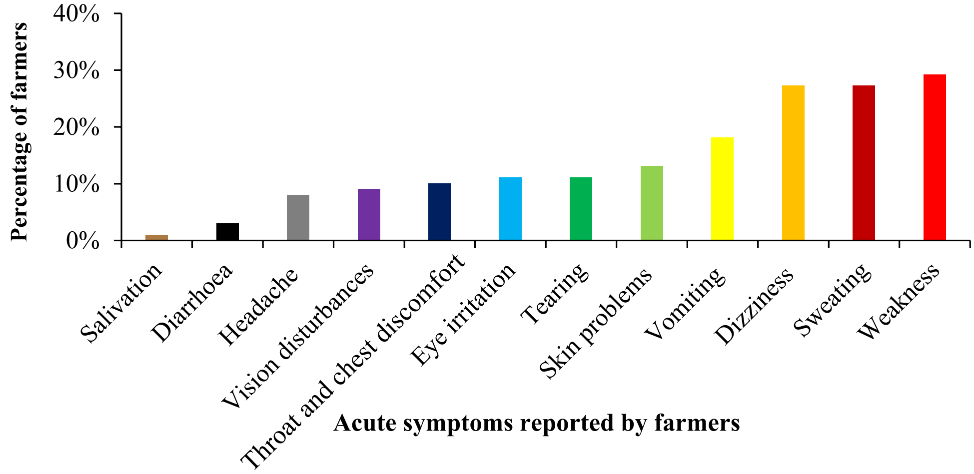

Fig. 3 Percentage of strawberry farmers suffering from acute health symptoms

frequently used pesticides for strawberry cultivation were imidacloprid (33% of the farmers), chlorpyrifos (29% of the farmers) and mancozeb (26% of the farmers) (Table S3). Insecticides were used more frequently than fungicides. WHO's class Ia insecticide such as parathion-methyl (banned organophosphate) was also still in use. Very few farmers practiced the use of biopesticides (≤ 10%). About half of the pesticides used by the farmers were not approved in the EU (Table S4). In a group discussion, few farmers truthfully mentioned that in some cases they applied pesticides much higher doses than recommended. Safe pesticide use practices are influenced by education and training. In our study, most farmers were illiterate and never attended pesticide training, therefore lacked the habit of reading the risk information displayed on pesticide packets and containers. Majority of the key informants concluded that hands-on training program designed for farmers' and retailers' safe handling of pesticides is in its infancy. Therefore, most of the farmers underestimated the potential risks of pesticides that accounted a significant misuse/mishandling during spray. Knapsack sprayers were used by the farmers. In most cases, calibration of the sprayers and application was not performed which increases pesticides misuse and mishandling. As reported by Damalas and Khan (2016), the main cause of the higher concentrations of pesticide residues in fruits include overuse, misuse and omission of time intervals between applications and the harvest. Safe usage of pesticides and adoption of pesticide reduction behaviors among farmers have been influenced by education, attitude, income, training, government subsidies and incentives (Liu et al. 2023). In this study, farmers were trained by an agricultural extension agent nominated by the HIME BERRY, henceforth, farmers never mixed fungicides and insecticides as cocktails in the fields. However, Ethiopian farmers preferred cocktail spraying in the fields to save time and money (Mengistie et al. 2017). The number of active ingredients that farmers used in the strawberry fields ranged from 0 to 6 (mean 1.60, SD ± 1.02).

Table 2 The goodness of fit and indices of the PMT model

Construct	CR	CA	GoF
Perceived threat severity	0.638	0.603	0.350
Perceived threat vulnerability	0.627	0.542	
Maladaptive rewards	0.726	0.733	
Fear	0.755	0.757	
Response efficacy	0.850	0.845	
Self-efficacy	0.600	0.559	
Response cost	0.700	0.688	
Protection motivation	0.790	0.789	

CR Composite reliability, *CA* Cronbach's alpha, *GoF* Goodness-of-fit.

Health Related Symptom Response of Farmers (Short-Term Illness, 24-h)

About 62% of the farmers experienced short-term illness after pesticide application. The most commonly self-reported toxicity symptoms related to pesticide poisonings were headaches (29% of the farmers), dizziness (27%) and sweating (27%) (Fig. 3). Table S5 shows the acute symptoms related to pesticides used in the field. The long-term exposure to pesticides may even cause severe health consequences such as neurological and respiratory problems, including cancer.

A similar study conducted in other regions of Nepal also reported headache as the most common toxicity symptom among vegetable farmers (Bhandari et al. 2018). Moreover, similar findings were observed by farmers from India (Lari et al. 2021), Kenya (Marete et al. 2021), Bangladesh (Akter et al. 2018), Brazil (Evaristo et al. 2022) and Pakistan (Mehmood et al. 2021).

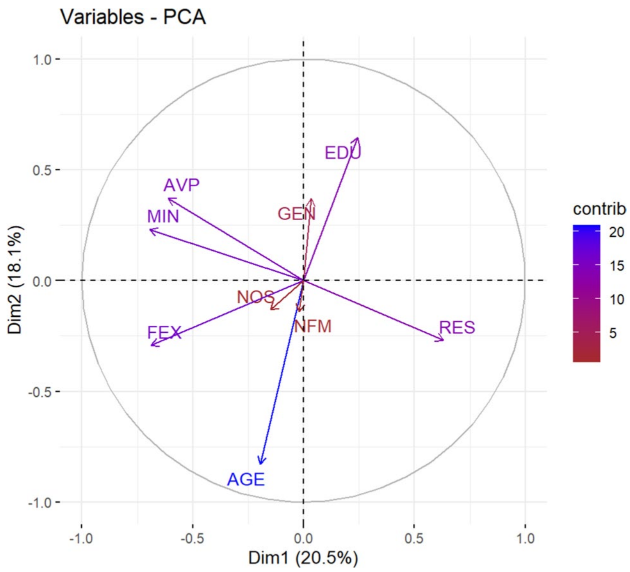

Fig. 4 PCA of variables affecting the number of acute symptoms of farmers. *NOS* number of acute symptoms, *AGE* age of farmers, *NFM* number of family members, *FEX* farming experiences, MIN monthly income, *AVP* area of vegetable production, *GEN* gender of farmers, *EDU* education, *RES* residence of farmers

Different Indices and Goodness of Fit of the Model

The composite reliability (CR), Cronbach's alpha (CA) and a goodness-of-fit (GoF) of the model is presented in Table 2. In the table, the CR value was ≥ 0.7 for four constructs while it was between 0.6 and 0.7 for the remaining constructs, indicating good enough to accept the reliability (Hair et al. 2014). The CA values were obtained between relatively high to acceptable limits (Taber 2017). Likewise, the value of GoF was 0.35, indicating robust fit of the model.

PCA was performed on the basis of socioeconomic variables of farmers to show factors contribution the number of acute symptoms in farmers (Fig. 4). Dim1 and Dim2 represent two different axes with their corresponding percentage. The direction of the arrows (AGE, RES, NFM, EDU, GEN, AVP, MIN, FEX and NOS; their abbreviation in the Fig. 4 caption) represents the relationship between each other, and each variable and the aforementioned axes. The length and color of these arrows (as indicated in the heat map) represented a contribution of the variables to the axis 1 and 2. Of all the variables, age and farming experience significantly contributed to the number of acute symptoms reported by farmers (Table 3 and Fig. 4). The variables that are opposite in direction such as education indicated opposite influences on the number of symptoms. Gender and number of family members locating near the origin had a minor contribution to the number of acute symptoms, a finding further supported by the heat map.

A farmers' age positively affected the number of acute symptoms, whereas education negatively affected their acute symptoms. About half of the farmers in this study were youths (viz. ≤ 35 years old) and had low experiences of agriculture. They perceived acute symptoms (Fig. 3) as a seasonal disease in humans due to flu rather than problems related to pesticide intoxications that accompanied fewer complaints and lower adherence of safety gears during our survey. In a similar study conducted in other regions of Nepal, young farmers perceived higher barriers related to safety measures and had low adherence to good agricultural practices (Bhandari et al. 2018). Most strawberry farmers were either illiterate or had completed only elementary levels of education. Because of this low levels of education farmers perceived pesticides as medicines and often used in their fields more than recommended to get a quick relief from agricultural problems related to diseases and pests. As a consequence, they had more complaints related to pesticide intoxications as reported in this study.

Most farmers (> 80%) purchased and sprayed pesticides only when required, while only a few farmers (< 5%) managed it well in advance and followed calendar method for spray. "I apply pesticides after I see the pests and diseases in fields", a young farmer stated in a group discussion. The leftover pesticides were stored in a shelter close to their fields. Empty pesticide packets and containers were observed during our field visit (Fig. 5A). About half of the farmers prepared and rinsed backpack sprayers carelessly close to their houses and applied pesticides without PPE (Fig. 5C), which vouches for their negligence towards pesticides exposure. Similar behaviors of strawberry farmers were observed in Vietnam (Houbraken et al. 2016). Most farmers (> 70%) inhabited very close (< 100 m) to their treated strawberry fields. Farmers living in such fields will be exposed to pesticides from direct spray as well as drift from nearby fields. Because of the exposure farmers reported several acute symptoms related to pesticides toxicity. Past evidence showed that farmers and their family members living close to their agricultural fields are more exposed to chemical pesticides than others living faraway (Hyland and Laribi 2017).

Farmers' residence showed significantly negative correlation with their reported pesticide toxicity symptoms (24-h) (Fig. 5 and Table 3).

The reason might be due to the lack of education and training, as well as, gender disparities among farmers. Knowledge and training through education is crucial for minimizing pesticide intoxication (Mubushar et al. 2019). Illiterate, female farmers felt that pesticide intoxications were normal phenomena and handled pesticides carelessly (Kafle et al. 2021).

The path analysis of farmers indicated a significant positive and negative effect on their reported symptom response

Table 3 Correlation matrix of the demographic variables and the constructs of the PMT model

	AGE	GEN	RESI	EDU	FAM	AREA	FEX	MSIN	MIN	NOS	PTSE	PTVU	MARE	FEAR	REEF	SEEF	RESC	PRMO
AGE	1																	
GEN	− 0.145	1																
RESI	0.145	− 0.096	1															
EDU	**− 0.407*****	0.052	0.056	1														
FAM	0.097	− 0.190	0.074	0.033	1													
AREA	− 0.100	0.038	**− 0.247***	0.038	0.072	1												
FEX	**0.321****	− 0.100	**− 0.279****	− 0.143	− 0.055	0.192	1											
MSIN	0.004	− 0.112	− 0.030	− 0.047	− 0.076	0.078	0.012	1										
MIN	− 0.030	− 0.020	**− 0.257****	− 0.004	0.065	**0.401*****	**0.266****	− 0.051	1									
NOS	0.085	0.097	**− 0.223***	− 0.092	− 0.035	− 0.126	0.031	− 0.085	0.009	1								
PTSE	0.029	− 0.008	0.072	0.012	0.018	0.162	0.183	− 0.093	0.086	0.002	1							
PTVU	0.181	− 0.096	**0.246***	− 0.027	0.115	− 0.047	0.055	**0.362*****	− 0.088	0.114	**0.398*****	1						
MARE	0.093	− 0.047	− 0.044	− 0.035	0.121	− 0.133	0.174	0.182	0.031	0.035	**− 0.298****	− 0.133	1					
FEAR	− 0.109	**0.259****	0.109	0.103	− 0.006	0.022	− 0.088	0.077	0.083	0.181	**0.345*****	**0.339*****	0.004	1				
REEF	− 0.071	− 0.064	− 0.006	0.094	0.017	0.067	**0.221***	− 0.079	**0.255***	0.150	**0.547*****	**0.219***	0.071	**0.347*****	1			
SEEF	− 0.038	0.025	0.048	**0.244***	0.100	0.099	− 0.037	**− 0.208***	0.051	0.065	0.003	0.172	0.091	**0.379*****	**0.250***	1		
RESC	− 0.002	**− 0.201***	− 0.105	− 0.243	0.020	0.010	0.145	− 0.044	− 0.024	0.087	0.019	**0.281****	**0.427*****	0.046	0.118	0.005	1	
PRMO	− 0.027	0.048	− 0.003	0.025	− 0.034	**0.261****	**0.232***	0.014	0.160	**− 0.228***	**0.436*****	0.136	− 0.107	0.191	**0.387*****	0.109	− 0.060	1

AGE age of respondents, *GEN* Gender of respondents, *RESI* Residence, *EDU* Education level, *FAM* Number of family members, *AREA* Area under strawberry cultivation, *FEX* Strawberry farming experience, *MSIN* Main source of income, *MI*N Total monthly income, *NOS* Number of symptom responses, *PTSE* Perceived threat severity, *PTVU* Perceived threat vulnerability, *MARE*, Maladaptive rewards, *FEAR*: Fear of farmers, *REEF* Response efficacy, *SEEF* Self-efficacy, *RESC* Response cost, *MINC* Monthly income, *PRMO* Protection motivation

*, ** and *** in bold represented significant correlation at the levels 0.05, 0.01, and 0.001, respectively

Fig. 5 Pesticide containers observed during a field visit (**A**), female farmer survey (**B**), a farmer spraying pesticides without PPE (**C**), and a male farmer survey and his field visit (**D**)

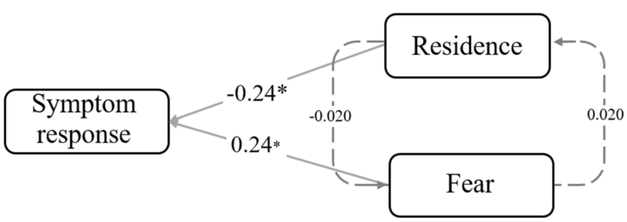

Fig. 6 Structural equation modeling of factors affecting the symptom response of strawberry farmers. * Significant at $p<0.05$

in relation to pesticide usage (Fig. 6). Fear (direct path coefficient, DPC = 0.24) had strong positive effects on farmers' response to acute symptoms of pesticide toxicity, while residence (DPC = – 0.24) had strong negative effects. Farmers who perceived susceptibility of potential health risks of pesticides toxicity showed positive effects on their symptom response. Farmers' residence showed negative effects which might be due to the difference in their pesticide knowledge and skills.

The path analysis of farmers' symptom response indicated that farmer's fear (direct path coefficient, DPC = 0.24) had strong positive effects on their reported acute symptoms. Similarly, residence, viz., areas proximity to their farm fields (indirect path coefficient, IPC = – 0.02) had a minor negative effect on fear, which might be due to cognitive and social proximities. Besides, geographical proximity affected the knowledge sharing among banana farmers in Rwanda (Kabirigi et al. 2022).

Pesticide Protective Behavior of Farmers

The percentages of farmers using personal protection equipment (PPE) was minimal (< 10%). More than 90% of the farmers claimed that using safety measures such as masks, hand gloves, hat and eye glasses made them uncomfortable during work to work in their fields. Discomfort and

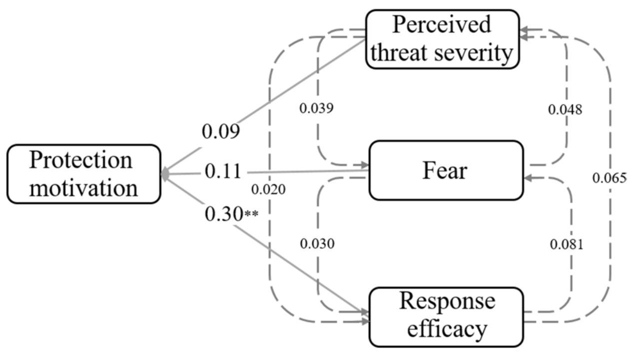

Fig. 7 Structural equation modeling of factors affecting the protection behavior of strawberry farmers. ** Significant at $p < 0.01$

unavailability were the major barriers for farmers not using protective measures in Nepal (Bhandari et al. 2018). Farmers in Ghana (Quansah et al. 2019), India (Kumari and Reddy 2013), and Armenia (Tadevosyan et al. 2013) perceived similar barriers and did not use protective measures during pesticide application. A female farmer in a group discussion stated, "I never use gloves and eye glass during spray. These items are not important, but I use mask and handkerchief to cover my face and head, respectively. Individuals with low coping appraisal perceived a high threat appraisal that can switch them into a non-protective behavior such as rejection or negligence (Bubeck et al. 2013). Lack of confidence or trust in choosing the best methods to protect themselves may be a serious obstacle to taking protection measures (Bubeck et al. 2018).

Our study showed that farmers followed poor protective behavior, which is consistent with the findings of past studies (Bagheri et al. 2019b; Savari and Gharechaee, 2020), while good practices during pesticide handling could decrease the incidences of onset symptoms of pesticide poisonings. The protective behavior of farmers was affected by several constructs, such as, perceived threat vulnerability, perceived threat severity, fear and response efficacy (Fig. 7 and Table 3).

The path analysis of farmers indicated that a perceived threat severity (direct path coefficient, DPC = 0.09) had minor positive effects on the protection behavior of farmers, while fear (direct path coefficient, DPC = 0.11) had moderate effects. In a similar study conducted in Iran, perceived severity of the negative effects of chemical pesticides showed the strongest positive effect of citrus farmers on their Integrated Pest Management (IPM) adoption behavior (Abdollahzadeh et al. 2024). Similarly, response efficacy (direct path coefficient, DPC = 0.30) indicated strong positive effect. Perceived threat severity (indirect path coefficient, IPC = 0.02) and fear (indirect path coefficient, IPC = 0.03) had only minor positive effects on response efficacy.

Limitations and Future Recommendations

This study relied on the constructs of the PMT, whereas other theories such as theory of planned behavior might also be suitable for studying the pesticide safety behavior. For a holistic understanding of the behavior, two relevant theories can be incorporated. Additionally, the use of constructs from different theories may have greater significance on results, resulting a precise conclusion. The study was not extensive and covered only a small part of the geographical area where strawberry farming is done in Nepal. Therefore, the generalization of the findings is limited. Second, self-reported acute symptoms of farmers have no acceptable evaluation tool. Third, study's reliance on self-reported symptoms could introduce bias. Nevertheless, this study enriched our understanding of the effective factors on protective behavior of strawberry farmers in Nepal. Monitoring of micro plastic in addition to pesticide residues in strawberry should be conducted for maintaining food safety in the country. Considering resource constraints in Nepal, the government can at least develop hands-on training modules focusing on the safe use of chemical pesticides and their toxicity and implement in rural areas of strawberry farms.

Conclusions and Recommendations

The current study was based on theoretical framework studies focusing on farmers' protective behaviors among farmers in developing nations. This study explored farmers' protective behavior in safe pesticide handling in Kakani Rural Municipality, Nepal by using a protection motivation theory (PMT). Farmers often practice poor protective behavior and were at high risk of pesticides exposure. Results from the PMT revealed that response efficacy and fear were the most reliable positive predictors of farmers' safe protective behavior and their reported acute symptoms, respectively (hypotheses such as H1, H2 and H3 accepted). Similarly, residence was the most significant negative predictor of farmers' symptom response (H4 accepted). Improving farmer's beliefs towards safe pesticide use and making them aware about the linkages of pesticides with fatal diseases through education and training can help improving their safety behavior. The outcomes of this study can be considered as a useful tool for policy makers to formulate legal frameworks for assuring sustainable use of pesticides. The presented correlations are resourceful for future scholars for conducting meta-analyses. Moreover, future researchers are recommended to integrate other theoretical approaches and frameworks, such as, the theory of planned behavior, to achieve a holistic understanding of the factors influencing farmers' protective behavior related to pesticide use. Similar study can also be carried with other fruit farmers in different regions of Nepal for a broader pesticide use perspective. Whether or not strawberries grown in Nepal are safe to eat requires future research on pesticide analytics.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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