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Factors influencing the level of health risks from pesticide exposure among vegetable farmers

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ABSTRACT

Thai farmers have been known to extensively use cholinesterase inhibitors, such as organophosphate and carbamate insecticides. This cross-sectional descriptive study examined the factors influencing the level of health risks from pesticide exposure among vegetable farmers. The data were gathered from 195 farmers using the Farmer's Work Risk Assessment from the Pesticide Exposure form. The study found that over half of the farmers were in the lowest health risk category (65.64%). Some of the risk factors identified were low education level (OR = 0.42, 95% CI = 0.19–0.93, p-value = 0.033), consumption of vegetables possibly containing pesticide residue (OR = 2.88, 95% CI = 1.43–5.79, p-value = 0.003), 8–14 days monthly average use of pesticide (OR = 0.21, 95% CI = 0.07–0.69, p-value = 0.010), and the application of pesticides in agriculture for insect control (OR = 0.30, 95% CI = 0.10–0.87, p-value = 0.027). Therefore, to reduce the health risks associated with pesticide exposure, farmers must be educated and trained to safely use pesticides to continue promoting naturally occurring and ecologically friendly pesticides.

Keywords: pesticides; health risk assessment; influencing factor; vegetable farmer; Thailand

1. INTRODUCTION

Crop productivity growth is the overall goal of Thailand's growing agricultural sector. Therefore, using chemical fertilizers for plant growth is encouraged, which also leads to the extensive use of pesticides. Yearly, imports of pesticides have tripled in size during the last decade, and the yearly chemical consumption rate per unit area has increased to 11% (Thammasri, 2021). In 2021, Thailand imported 136,101.30 tons of hazardous agricultural chemicals. The most imported chemical is pesticide (127,967.05 tons) comprising fungicide (24,248.16 tons), insecticide (29,554.17 tons), and herbicide (74,164.72 tons) (Office of Agricultural Regulation, 2021). In 2020, the entire nation marked 5,721 cases of pesticide poisoning, at a rate of 8 cases per 100,000 population (Department of Disease Control, 2020). This implied that most of these pesticides were utilized in the country's northern, northeastern, and central regions based on agricultural activities and land areas. In the last 2 decades, most farmers in Thailand, Lao PDR, and Cambodia along the lower Mekong basin have used large quantities of agrochemicals, especially in rice farming. The most often used agrochemicals have been pesticides, including chemical fertilizers, insecticides, fungicides, and herbicides (Petchuay, 2017). According to previous studies, education level, work experience, knowledge level, and attitudes affect pesticide use practices. Recently, numerous participants have had acute health problems, and their symptoms strongly correlate with poor behavior in pesticide use (Kangkhetkron and Juntarawijit, 2021). According to the survey by Kongtip et al. (2018), different agricultural work carries different risks and hazards affecting farmers' health. Using personal protective equipment and other effective exposure prevention techniques was uncommon among the farmers who only farmed vegetables (Kongtip et al., 2018). A study conducted by Nganchamung et al. (2017), which aimed to determine the association between blood cholinesterase activity and organophosphate pesticide (OP) residues on hands among chili farmers in Ubon Ratchathani, Thailand, found that approximately 80% of the participants had OP residues on their hands and 50% of them experienced some acute health symptoms within 48 h of applying pesticides (Nganchamung et al., 2017).

According to the 2017 annual report of Nong Tae Subdistrict Health Promoting Hospital, a total of 1,630 households resided in 11 villages in Khi Lek subdistrict, Mueang district, Ubon Ratchathani, Thailand. The majority of the population engaged in agriculture. Farmers grow and sell vegetables, such as chilis, eggplants, radishes, mints, shallots, and cabbages, at the local markets and the markets in the neighboring provinces after the rice planting season. In villages 5, 8, 9, and 10, farmers cultivate vegetables and use high amounts of pesticides, especially chemicals containing carbamates and organophosphates (Boonkhao and Wongsafu, 2020). Due to prevailing abnormal serum cholinesterase among vegetable farmers in these villages, 51.18% of those who used pesticides on their farms had unsafe levels of health risks, and 48.03% were at risk (Boonkhao and Baukeaw, 2020). Acetylcholine, a neurotransmitter, overdose leads to cholinergic symptoms, such as cramps, increased salivation, lacrimation, and blurred vision (Whitmore et al., 2020; Peter et al., 2014). Cholinesterase antagonizes acetylcholine through hydrolysis (Fukuto, 1990). Organophosphates and carbamates provide an anticholinesterase activity, increasing acetylcholine.

In a previous study conducted in Ubon Ratchathani, Thailand, the researchers used the risk assessment method to determine the health risks related to farmers' pesticide exposure using the model developed by the Bureau of Occupational and Environmental Diseases, the Department of Disease Control, under the Ministry of Public Health. However, no studies have been conducted to determine the factors influencing the level of health risks from pesticide exposure among the farmers. If research results or data were available, it would have made it easier for the concerned organizations to reduce the farmers' health risks. Therefore, this study aims to identify the variables affecting the levels of health risks associated with farmer exposure to pesticides in Khi Lek subdistrict, Mueang district, Ubon Ratchathani province.

2. MATERIALS AND METHODS

2.1 Population and sample

The population of this study is 608 vegetable farmers in villages 5, 8, 9, and 10 in Khi Lek, Ubon Ratchathani. Equation 1 was used to determine a minimum sample size of 176.

$$n = \frac{NZ^2_{\alpha/2}p(1-p)}{[e^2(N-1)]+\left[Z^2_{\alpha/2}p(1-p)\right]} \quad (1)$$

where n = sample size
N = population
$Z\alpha/2$ = the coefficient under the standard normal curve at 95% confidence level, Z (0.025) = 1.96
p = proportion estimates; 0.80 obtained from literature reviews (Boonkhao and Wongsafu, 2020)
e = precision of estimate; 0.05

When the researchers conducted an accidental sampling in the four villages, 195 vegetable farmers agreed to fill out the questionnaire.

2.2 Research tools

The Work Risk Assessment Form of Farmers from Pesticide Exposure, created by the Bureau of Occupational and Environmental Diseases, the Department of Disease Control, was utilized in the study. The document is divided into three sections:

Part 1 contains general personal information including gender, age, education level, average monthly income, marital status, congenital diseases, information concerning pesticide use, the size of the area utilized for vegetable growing, type of pesticides used, and the duration of pesticide use before harvest.

Part 2 has 15 items regarding pesticide use and behavior at work. The behavioral score was used to determine the likelihood of pesticide exposure (Table 1).

Part 3 collects information about acute diseases or symptoms caused by pesticide use or exposure. If farmers experienced numerous symptoms, the researchers would choose the most severe symptom group for assessment. The data results in this section were used to assess the severity of health risks. The four levels of symptoms comprise asymptomatic, mild, moderate, and severe (Table 1).

The risk matrix was determined using the data from Parts 2 and 3. Farmers' health risks associated with pesticide exposure were categorized into five levels: low, moderate, relatively high, high, and very high (Table 1).

2.3 Research tool quality assessment

The questionnaire had a number of closed-ended questions. An item objective congruence index between 0.67 and 1.00 was obtained after three experts had verified the content validity.

Farmers from Ban Non Bon, Bung Wai subdistrict, Warin Chamrap district, were used as test subjects for the questionnaire's reliability. The confidence in the questionnaire was 0.72 after calculating Cronbach's Alpha Coefficient. The alpha coefficient must be 0.70 or above to be considered acceptable (DeVon et al., 2007).

2.4 Data collection

The researchers gathered the data by outlining the study objective, criteria, and details to the farmers and then requested that they complete the questionnaire on their own. After the ethics of using human subjects in research had been approved, the researchers gathered the data. The risk assessment was then carried out following Table 1, and the factors influencing individual farmers' level of health risks from pesticide exposure were examined.

Table 1. Health risks associated with pesticide exposure among farmers

The acute symptoms after pesticide exposure	The behavioral score		
	Low (15–24 score)	Moderate (25–30 score)	High (31–45 score)
Asymptomatic	Low	Moderate	Relatively high
Show any signs of group 1 symptoms (1 or more) (mild symptoms)	Moderate	Relatively high	High
Show any signs of group 2 symptoms (1 or more) (moderate symptoms)	Relatively high	High	High
Show any signs of group 3 symptoms (1 or more) (severe symptoms)	High	High	Very high

Source: The Division of Occupational and Environmental Diseases, the Department of Disease Control, the Ministry of Public Health, 2015.

2.5 Data analysis

General data on gender, age, education level, marital status, average monthly income, congenital diseases, pesticide use, and types of locally grown vegetables were analyzed using frequency and percentage.

Data from the risk assessment of pesticide exposure were analyzed using frequency and percentage.

Ordinal logistic regression statistics were used to analyze the factors influencing the risk of pesticide exposure in farmers.

3. RESULTS AND DISCUSSION

Over half of the subjects were female (54.36%); 63.59% of them were younger than 60 years old; 81.54% had completed elementary school education; 80.51% had no congenital diseases; 60.00% were chemical sprayers; 52.82% were chemical mixers; 32.09% had used pesticides within 8–14 days at the time of research; 40.54% used pesticide, on average, 8–14 days monthly; 87.18% utilized chemical insecticides; 52.97% had received training in pesticide use; and 89.50% had obtained knowledge about self-protection from the risks of using pesticides (Table 2). Since 60% of the farmers in this study used pesticide sprayers, with 32.09% of them making the mixture themselves and 40.54% applying pesticides monthly, there is a high possibility that the farmers were exposed to pesticides. This agrees with the study of Hobut and Bopthong (2018), where 57.5% of pesticide users continued to make the mixture themselves, and 51.7% used it more than 7 days a month (Hobut and Bopthong, 2018). Damalas and Koutroubas (2016) also found that farmers are most frequently exposed during the preparation, use, and cleanup of pesticide spray solutions and spraying equipment. Farmers who mix, pack, and spray pesticides may be exposed to these chemicals through spills, splashes, and direct contact because they do not have personal protective equipment or wear it inappropriately (Damalas and Koutroubas, 2016). In this research, 52.97% had received training in pesticide use. This raises the possibility that some lacked an understanding of how to use pesticides properly. As a study by Mrema et al. (2017) suggests, increased exposure to pesticides correlates with inadequate knowledge of the hazardous nature of pesticides (Mrema et al., 2017).

Table 2. Demographic characteristics of 195 farmers

Characteristics	No. of farmers	Percent (%)
1. Gender		
Male	89	45.64
Female	106	54.36
2. Age (years)		
<60	124	63.59
≥60	71	36.41
3. Minimum education level		
Primary education	159	81.54
Secondary education	13	6.67
Upper secondary education	21	10.77
Bachelor's degree or higher	2	1.02
4. Congenital diseases		
Yes	38	19.49
No	157	80.51
5. Contact with chemicals (can respond to multiple items)		
Chemical mixer	103	52.82
May consume vegetables and fruits that have chemical residues	69	35.38
Chemical sprayer	117	60.00

Table 2. (Continued)

Characteristics	No. of farmers	Percent (%)
5. Contact with chemicals (can respond to multiple items)		
Stay in the spraying area	83	42.56
Chemical spraying service	1	0.51
May directly interact with chemically treated fruits and vegetables	38	19.49
6. Most recent use of pesticides (day) (n = 187)		
1–2	27	14.44
3–7	57	30.48
8–14	60	32.09
≥15	43	22.99
7. Frequency of pesticide use per month (day/month) (n = 185)		
1–2	17	9.19
3–7	22	11.89
8–14	75	40.54
≥15	71	38.38
8. The objectives of pesticide use in agriculture (can respond to multiple items)		
Insect control	170	87.18
Weed control	61	31.28
9. Having received training in self-protection in pesticide use (n = 185)		
Yes	98	52.97
No	87	47.03
10. Having obtained knowledge about self-protection from the risks of pesticide use (n = 181)		
Yes	162	89.50
No	19	10.50

The level of health risk associated with pesticide exposure among 65.64% of the farmers was low. A further 26.67% were deemed at moderate risk and 7.69% at relatively high risk (Table 3). Most farmers reported no or mild symptoms when questioned about the signs and symptoms of acute disorders after pesticide exposure. The abnormal symptoms each farmer experienced varied depending on their personal characteristics (gender, age, weight), sensitivity and resistance to chemicals, exposure pathways, length of exposure, and the type and amount of chemicals they were exposed to. These factors can discriminate the different levels of symptom severity that the farmers had experienced after pesticide exposure (Kim et al., 2017 and Jensen et al., 2011). This could be one of the factors contributing to the lowest level of health risk associated with pesticide exposure among the farmers. However, this study found that 7.69% of farmers had a high relative risk. The study found that farmers in this group did not experience abnormal symptoms after exposure to chemicals, but it was evident that they engaged in improper behavior when handling chemicals, such as soaking themselves in pesticides while working, failing to wash their hands frequently enough before eating or drinking, failing to wear chemical-resistant rubber gloves while handling chemicals, and failing to immediately change contaminated clothing or take a shower and clean up. Farmers are mainly exposed to pesticides through dermal, oral, and respiratory pathways. Farmers with direct or indirect exposure to pesticides run the risk of developing chronic illnesses and acute adverse effects (Tudi et al., 2022).

Table 3. Risk levels of farmers after exposure to pesticides (n = 195)

Health risk level	Frequency	Percent (%)
Low	128	65.64
Moderate	52	26.67
Relatively high	15	7.69

The research identifies the factors associated with the level of health risks from pesticide exposure among vegetable farmers (Table 4). The parallel lines test was used to show that the regression coefficients in each model were identical (X2 = 10.31, df = 6, p-value = 0.112). The association between pesticide exposure and health risks among vegetable farmers showed that the farmers with only a primary education were 0.42 times more health risk of pesticide exposure than those with a higher education degree (OR = 0.42, 95% CI = 0.19–0.93, p-value = 0.033). This might be attributed to the fact that farmers with only a primary education had a longer history of pesticide use than those with higher education; it was found that 90.72% of the farmers with primary education had used pesticides for at least 5 years compared to 9.28% of the farmers with higher education. This showed that the farmers with primary education had more experience applying pesticides and protecting themselves. A study by Wannasiri (2018) investigating farmers' experiences in using chemicals in pomelo gardens in Nakhon Pathom province found that the farmers who had grown pomelos for more than 10 years were aware of the risks associated with pesticides and had learned how to protect themselves (Wannasiri, 2018). In this research, the farmers who might consume pesticide-contaminated fruits and vegetables had a

2.88 times greater risk of pesticide contact than those who did not (OR = 2.88, 95% CI = 1.43–5.78, p-value = 0.003). As stated in a 2017 study by Elgueta et al. (2017), 27% of all leafy vegetables contained pesticide residues at levels higher than the maximum residue limits for each active ingredient. This research found that the farmers who used pesticides an average of 8–14 days monthly had a 0.21 times higher health risk from pesticide exposure than those who used them an average of 1–2 days monthly (OR = 0.21, 95% CI = 0.07–0.69, p-value = 0.010). This may be because the farmers in the group who used pesticides 8–14 days monthly felt more at risk from their relatively frequent chemical use. As a result, they had effective ways of protecting themselves from pesticides. This conforms to a study by Wannasiri (2018), which found that farmers had to take precautions and safety measures to protect themselves when they used a high amount of pesticides, including covering their bodies, avoiding direct contact with chemicals, and keeping their spraying equipment in a designated location without grouping it with other items. Our research showed that the farmers who used chemical pesticides to control insects were 0.30 times more prone to health risks from pesticide exposure than those who did not (OR = 0.30, 95% CI = 0.10–0.87, p-value = 0.027) (Table 4). Since 94.85% of the farmers had at least 5 years' experience in pesticide application, they had more effective techniques and tools for pesticide protection. Additionally, the area is an agricultural location where high amounts of pesticides are applied. However, some farmers avoid using chemical pesticides. Even if there is no chemical use or only a small amount of herbicides present, there is still a chance of chemical exposure from surrounding agricultural areas.

Table 4. Factors influencing the level of health risks associated with pesticide exposure among vegetable farmers

Factor		b	SE(b)	OR	95% CI of OR		p-value
					Lower	Upper	
Threshold	**[matrix = 1]**	−0.31	0.30	-	−2.93	0.30	0.314
	[matrix = 2]	1.91	0.36	-	−0.73	2.53	<0.001
Education Level (Higher than primary education*)							
Primary education (Fin)		0.87	0.41	0.42	0.19	0.93	0.033
Consumption of vegetables and fruits that have chemical residues (Not consume*)							
Consume (Eat)		−1.06	0.36	2.88	1.43	5.79	0.003
Average pesticide use per month (1–2 days*)							
3–7 days (L-TN)		−1.56	0.44	0.81	0.22	3.01	0.753
8–14 days (M-TN)		−0.22	0.52	0.21	0.07	0.69	0.010
>14 days (H-TN)		−0.01	0.54	1.01	0.35	2.92	0.981
Pesticide use for insect control (No*)							
Yes (Yes)		1.21	0.55	0.30	0.10	0.87	0.027

Note: *Reference, Nagelkerke R2 = 0.284

Equation 2 and Equation 3 were developed using the model derived from the analysis of the variables influencing the levels of health risks associated with pesticide exposure among vegetable farmers.

$$Ln\left[\frac{P(QH-matrix)}{P(M-matrix\ or\ L-matrix)}\right] = -0.31 - 0.87(Fin) + 1.06(Eat) + 1.56(L-TN) + 0.22(M-TN) + 0.01(H-N) - 1.21(Yas)Ln \quad (2)$$

$$Ln\left[\frac{P(QH-matrix\ or\ M-matrix)}{P(L-matrix)}\right] = 1.91 - 0.87(Fin) + 1.06(Eat) + 1.56(L-TN) + 0.22(M-TN) + 0.01(H-TN) - 1.21(Yas) \quad (3)$$

It was found that all of the factors in the model significantly predicted the levels of health risks associated with pesticide exposure when the influence of the entire set of independent variables on the dependent variable was tested using the LR chi-square test. (LR chi-square = 48.79: p-value 0.001). The forecast accuracy of the model is 15.56%.

4. CONCLUSION

Although most of the farmers in Khi Lek, Mueang, Ubon Ratchathani, Thailand, had the lowest level of health risk, this study found some factors associated with the levels of health risks from pesticide exposure among vegetable growers. The factors were consuming vegetables that may contain pesticide residues, using pesticides 8–14 days monthly, and applying pesticides in agriculture for insect control. In conclusion, to protect farmers and consumers, relevant agencies should encourage farmers to learn proper pesticide handling practices and promote naturally occurring and ecologically friendly pesticides.

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