CHEMICAL FERTILIZER USE AND ACUTE HEALTH EFFECTS AMONG CHILI FARMERS IN UBON RATCHATHANI PROVINCE, THAILAND

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ABSTRACT:

Background: Chemical fertilizer use has increased globally over the past decades in agricultural countries such as Thailand. Currently, there is limited information regarding health effects related to chemical fertilizer exposure in Thailand. This study aimed to describe patterns of fertilizer use and to determine the prevalence of and factors associated with acute health effects related to chemical fertilizer exposure among chili farmers.

Methods: A cross-sectional descriptive study was conducted in Hua Ruea sub-district, Muang district, Ubon Ratchathani province in April 2016. Seventy-six chili farmers, directly contacting with chemical fertilizers, participated in the study. Face to face interviews were performed to gather information e.g. participant characteristics, frequency and kinds of fertilizer use, behaviors regarding chemical fertilizer use i.e. the use of personal protective equipment and hand hygiene, symptoms experienced while working with chemical fertilizers. Descriptive statistics were used to describe information. Chi-square test, Fisher's exact test, independent t-test, or Mann-Whitney test were used to compare differences of participant characteristics between a group with and without acute health effects. Binary logistic regression analysis was used to explore factors associated with having health effects.

Results: All chili farmers used both chemical and organic fertilizers in chili farms. Most of them used chemical fertilizers 1-3 times monthly (80.3%). NPK fertilizer (formula 15-15-15) and urea fertilizer (formula 46-0-0) were commonly used. Improper behaviors regarding chemical fertilizer use were found e.g. handling chemical fertilizers with bare hands, and no personal protective equipment. About 26.3% of them reported having some symptoms within 48 hours while working with chemical fertilizers. Most common symptoms were coughing or sneezing (15.8%) and skin irritation or itching (14.5%). Using chemical fertilizers more than 3 times per month (OR_{adjust} = 5.04, 95% CI: 1.04-24.56), alcohol consumption (OR_{adjust} = 4.12, 95% CI: 1.24-13.67), and smoking habits (OR_{adjust} = 4.30, 95% CI: 1.18-15.67) were the risk factors of having health effects related to chemical fertilizer exposure.

Conclusion: Chili farmers regularly used a variety of chemical fertilizers linked to increased risks of chemical fertilizer exposure. The prevalence of acute health effects related to chemical fertilizer exposure in chili farmers was relatively low. This study suggested that chili farmers should be more concerned about the safe use of chemical fertilizers to prevent health risks of chemical fertilizer exposure. Additionally, further investigate acute and long-term health effects of chemical fertilizer exposure are desirable.

Keywords: Chemical fertilizers; Chili farmers; Health effects; Occupational exposure

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INTRODUCTION

Chemical fertilizers are commonly used to fill soil nutrients to enhance agricultural yields.

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Although using chemical fertilizers provides significant benefits to society, it can be harmful if using heavily and improperly. In general, chemical fertilizers compose of principal nutrients requiring for plant growths such as nitrogen, phosphorous, and potassium (NPK) as well as micronutrients such as copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and heavy metal contaminants such as arsenic (As), cadmium (Cd), chromium (Cr), and lead (Pb) [1-3]. These hazardous elements may potentially cause adverse health effects even exposed at the low levels.

Existent studies have documented that the exposure to chemical fertilizers linking to contact dermatitis [4-6] and respiratory problems [7-9]. For example, the case reports exhibited that contact dermatitis was caused by nickel in fertilizers found in chemical laboratory factory workers, by phosphates showed in fertilizer factory workers [5], and by calcium ammonium nitrate reported in farmers used fertilizers [6]. Bhat and Ramaswamy [7] demonstrated that chemical fertilizer exposure decreased lung functions possibly causing restrictive type of lung disorders in long term. Zhang and colleagues [8] found that exposure to chemical fertilizers significantly increased risk of respiratory symptoms. Ramah and coworkers [9] suggested that exposure to ammonia at higher level were significantly related to an increased prevalence of respiratory symptoms and an acute reduction of lung functions among urea fertilizer factory workers. Gorman and colleagues [10] revealed that tree planters working with chemical fertilizers did not have relation to increased inhalation or dermal exposure to metal contaminants such as As, Cd, Cr, Pb, Ni; and they also found a weak relation between dermal and respiratory irritation and working with chemical fertilizers [2].

World's chemical fertilizer consumption has grown continually over the past decades. It estimated that the global demand for chemical fertilizers was increased from 184.6 million tons in 2014 to 186.6 million tons in 2015; and it is predicted to reach 199 million tons in 2019 [11] . Thailand is one of the world's largest agricultural producers and the important chemical fertilizer consumers. As the Thai government's policy, the importation and use of chemical fertilizers in Thailand began to grow dramatically since 1970s; and its growth was elevated up to 100 times from 1961 to 2004 [12]. The Office of Agricultural Economics (OAE) estimated that 3.5 million tons of chemical fertilizers were annually used in agriculture during 1994-2004 [13]. The recent data in 2011-2015 showed that over 5.4 million tons of chemical fertilizers were imported into the country each year, valued at 71,378 million THB by year (1 USD ≈ 34.6 THB) [14].

Farmers are occupationally exposed to chemical fertilizers while applying fertilizers to soil and plants. Thus, they may potentially have health effects associated with chemical fertilizer exposure such as respiratory and dermal symptoms e.g. respiratory irritations, cough, chest tightness, skin irritation, rashes, and contact dermatitis [4-6]. Previous studies highlighted that farmers in Ubon Ratchathani province, where ranked second in the largest agricultural area and highest number of farmers in Thailand, extremely used agrochemicals (i.e. pesticides and chemical fertilizers), particularly in chili productions [15, 16]. It was also evidenced that shallow groundwater in agricultural areas in this province was contaminated with heavy metals due to overusing chemical fertilizers for a long time [17, 18]; in addition, it had evidences regarding the excessive use of chemical fertilizers related to nitrate contamination in groundwater in other areas [19]. Consequently, people living in these agricultural areas might face to health risks related to chemical fertilizers. It found only one study reported the prevalence of symptoms from chemical fertilizer exposure (e.g. eye irritation, difficulty in breathing, and runny nose, cough, or sneeze) among shallot farmers in Phayao province, Thailand [20]. However, a study regarding health effects related to chemical fertilizer exposure in Thailand is limited. Furthermore, there is a lack of national database and current information regarding patterns of chemical fertilizer in Thailand. This study aimed to describe patterns of fertilizer use (e.g. frequency of chemical fertilizer use per month, kinds of fertilizer use, behaviors regarding chemical fertilizer use), and to determine prevalence of and factors associated with acute health effects related to chemical fertilizer exposure among chili farmers.

MATERIALS AND METHODS

A cross-sectional descriptive study was performed in Hua Ruea sub-district, Muang district, Ubon Ratchathani province, Northeastern Thailand during April 2016 (chili growing seasons). This area was chosen due to the large number of farmers and agricultural areas. Hua Ruea sub-district had a total area of 3,229 hectare with an estimated population

of 9,075 people living in 2,632 households [21]. More than 84% of the total areas were under cultivation [21]. Chili is one of the famous crops of this area. Chili farming is annually done around August and May (≈ 8-9 months/ crop). All chili farmers in two selected villages with a high number of chili farmer households were recruited. Chili farmers, who met the inclusion criteria and represented as the head of households, were purposively selected (one representative farmer per household). The inclusion criteria were farmers lived in the study area at least 1 year, aged 18 years or older, grew a chili crop and used chemical fertilizers in their farms. A total of 76 chili farmers willingly participated in the study.

Measurement tool

Face-to-face interview was administered to all participants by trained interviewers. The interview included participant characteristics, patterns of fertilizer use (e.g. frequency of chemical fertilizer use per month, kinds of fertilizer use, behaviors regarding chemical fertilizer use), and 5 respiratory and dermal symptoms related to chemical fertilizer exposure (e.g. cough or sneeze, runny nose, chest tightness, skin irritation or itching, skin rashes) within 48 hours while working with chemical fertilizers during past 2 months before interviewed. Only 5 respiratory and dermal symptoms were focused on in this study because of no other symptoms reported by participants. Additionally, frequency and kinds of pesticide use as well as acute symptoms related to pesticide exposure were interviewed; however, this information was not described in details, as it was previously published elsewhere.

Data analysis

All data were analyzed with the SPSS version 16.0. Descriptive statistics was used to describe participant characteristics, patterns of fertilizer use, and prevalence of health symptoms related to chemical fertilizer exposure. Having acute health effects related to chemical fertilizer exposure, a dependent variable classified into 2 groups (0 = no, 1 = yes), was defined as "no" if participants reported having none of acute symptom related to chemical fertilizer exposure; it was defined as "yes" if participants reported having at least 1 symptom. The comparisons of participant characteristics between a group with acute health effects and a group without acute health effects were performed by using a Chi- square test and Fisher's exact for qualitative variables; and an independent t-test and Mann-Whitney test were used for quantitative variables. Binary logistic regression analyses were conducted to obtain odds ratios (OR); and 95% confidence intervals (95% CI) was used to explore factors associated with having health effects related to chemical fertilizer exposure by using entry method. The dependent variable was having acute health effects related to chemical fertilizer exposure (0 = no, 1 = yes). The independent variables included quantitative variables e.g. age, areas of chili farms, number of years working in chili farming, and qualitative variables e.g. gender (0 = females, 1 = males), education (0 = primary, 1= secondary or higher), having health problems (0 = no, 1 = yes), alcohol consumption (0 = no, 1 = yes), smoking habit (0 = no, 1 = yes), having other family member working on chili farms (0 = no, 1 = yes), having other crops during chili growing season (0 = no, 1 = yes), frequency of chemical fertilizer use per month (0 = 1-3 times per month, 1= more than 3 times per month), using gloves and masks while working with chemical fertilizers (0= always, 1 = never or sometimes). Possible confounding factors were alcohol consumption and smoking habit because of its significant association with having health effects related to chemical fertilizer exposure proved by the chi-square tests. In addition, based on our interviews, all participants involved in pesticide application, and 39.5% of them had some respiratory and dermal symptoms such as cough, skin itching, and rashes within 48 hours while working with pesticides, so it might be a confounder. Thus, these factors were used for adjusting logistic regression analyses. The significance level was set at 0.05.

Ethical consideration

The study protocol was approved by the Ethics Review Committee for Research Involving Human Research Participants, Health Science Group, Chulalongkorn University with the certificate code COA no. 078/2558. All participants provided written inform consents prior to participate in the study.

RESULTS

Participant characteristics

As shown in Table 1, most participants were males (53.9%). An average age of participants was 49.71 years (SD = 9.19, range: 30-71 years). The majority of participants (76.3%) graduated primary

Table 1 Participant characteristics of 76 chili farmers

Characteristics	Total (n=76)	Having acute health effects †		*p-value*
		No (n=56)	Yes (n=20)	
Gender[1]				0.680
Male	41 (53.9%)	31 (55.4%)	10 (50.0%)	
Female	35 (46.1%)	25 (44.6%)	10 (50.0%)	
Age[2] (years)				
Mean (SD)	49.71 (9.19)	49.05 (9.18)	51.55 (9.20)	0.300
Education[3]				0.766
Primary	58 (76.3%)	42 (75.0%)	16 (80.0%)	
Secondary or higher	18 (23.7%)	14 (25.0%)	4 (20.0%)	
Having health problems[1]				0.345
No	52 (68.4%)	40 (71.4%)	12 (60.0%)	
Yes	24 (31.6%)	16 (28.6%)	8 (40.0%)	
Alcohol consumption[1]				0.018*
No	40 (52.6%)	34 (60.7%)	6 (30.0%)	
Yes	36 (47.4%)	22 (39.3%)	14 (70.0%)	
Smoking status[3]				0.035*
No	59 (77.6%)	47 (83.9%)	12 (60.0%)	
Yes	17 (22.4%)	9 (16.1%)	8 (40.0%)	
No. of years working in chili farming[4] (years)				
Median (IQR)	20.00 (11.00-26.00)	20.00 (11.00-26.00)	16.50 (11.00-24.75)	0.107
Area of chili farms[4] (hectare)				
Median (IQR)	0.32 (0.16-0.48)	0.32 (0.26-0.48)	0.32 (0.16-0.44)	0.159
Having other family member working on chili farms[3]				0.328
No	15 (19.7%)	13 (23.2%)	2 (10.0%)	
Yes	61 (80.3%)	43 (76.8%)	18 (90.0%)	
Growing other crops during chili growing season[1]				0.455
No	20 (26.3%)	16 (28.6%)	4 (20.0%)	
Yes	56 (73.7%)	40 (71.4%)	16 (80.0%)	

† Having acute health effects related to chemical fertilizer exposure defined as "No" if reported no symptom and "Yes" if reported at least 1 symptom; [1] Chi-square test; [2] Independent t test; [3] Fisher's exact test; [4] Mann-Whitney test; * Significant at $P < 0.05$; SD = Standard deviation; IQR = Interquartile range

education. About 31.6% of participants had some health problems such as hypertension and gastritis. Only 47.4% of participants were drinkers; and 22.4% were smokers. All participants worked on chili farms for a median of 20 years with a median farm area of 0.32 hectare. Furthermore, most of them (73.7%) grew other crops during the chili growing season such as spring onions, corianders, long beans; and they also used chemical fertilizers and pesticides for growing other crops. There was a significant difference in alcohol consumption and smoking habit found between participants with and without acute health effects related to chemical fertilizer exposure ($p = 0.018$ and 0.035, respectively).

Patterns of fertilizer use

All participants used both chemical and organic fertilizers in their chili farms (Table 2). The majority of participants used chemical fertilizers 1-3 times monthly (80.3%); and their last use was during 1-2 weeks ago (43.4%). A variety of chemical fertilizers were used in chili farms; and NPK fertilizer (formula 15-15-15) was mostly used. In addition, chicken manures were commonly used as fertilizers. Most participants had proper behaviors while working with chemical fertilizers such as always using gloves (56.6%) and masks (48.7%). However, percent of participants who did not use or sometimes used gloves or masks while working with chemical fertilizers seemed to be equal to those who always did. Almost all participants always washed hands with soap and water immediately after working with chemical fertilizers (Table 3).

Acute health symptoms related to chemical fertilizer exposure

Most participants (73.7%) reported having none

Table 2 Patterns of fertilizer use among chili farmers (n = 76)

Patterns of fertilizer use	Number of response (%)
Frequency of chemical fertilizer use per month	
1-3 times	61 (80.3%)
> 3 times	15 (19.7%)
Last use of chemical fertilizers	
1-2 weeks ago	33 (43.4%)
3-4 weeks ago	21 (27.6%)
> 4 weeks ago	22 (29.0%)
Storage area of chemical fertilizers	
Outside the house (e.g. chili farms, barns, sheds)	75 (98.7%)
Inside the house	1 (1.3%)
Types of chemical fertilizers used (Multiple responses)	
NPK fertilizer (15-15-15)	37 (48.7%)
Urea fertilizer (46-0-0)	34 (44.7%)
Others (e.g. 16-16-16, 25-7-7, 27-5-5)	24 (31.6%)
Types of organic fertilizers used (Multiple responses)	
Chicken manure	73 (96.1%)
Cattle manure	10 (13.2%)
Others (e.g. biofertilizers)	3 (3.9%)

Table 3 Behaviors regarding chemical fertilizer use among chili farmers (n=76)

Behaviors	Never	Sometimes	Always
Use gloves while working with chemical fertilizers	13 (17.1%)	20 (26.3%)	43 (56.6%)
Use mask while working with chemical fertilizers	17 (22.4%)	22 (28.9%)	37 (48.7%)
Wash hands with soap and water immediately after working with chemical fertilizers	0 (0.0%)	3 (3.9%)	73 (96.1%)

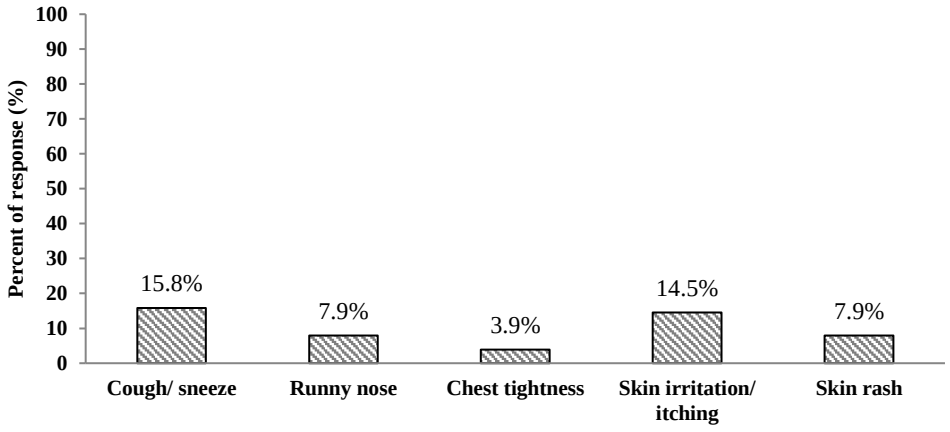


Figure 1 Prevalence of health symptoms related to chemical fertilizer exposure among chili farmers (n=76)

of health symptoms while working with chemical fertilizers; and the remaining (26.3%) reported experiencing 1-4 symptoms within 48 hours while working with chemical fertilizers during 2 past months. Three most reported symptoms were cough or sneeze, skin irritation or itching, and rashes (Figure 1).

Factors associated with having acute health effects related to chemical fertilizer exposure

The results of binary logistic regression analysis indicated that three factors had a significant association with having acute health effects related to chemical fertilizers; there were the frequency of chemical fertilizers per month (OR_{adjust} = 5.04, 95%

Table 4 Crude and adjusted odds ratios for having health effects related to chemical fertilizer exposure by binary logistic regression

Variables	Crude			Adjusted†		
	OR	95% CI	*p-value*	OR	95% CI	*p-value*
Gender[1]	0.81	0.29-2.24	0.680	0.88	0.29-2.67	0.826
Age	1.03	0.97-1.09	0.305	1.03	0.97-1.09	0.383
Education[2]	0.75	0.22-2.62	0.652	0.85	0.22-3.24	0.806
Having health problems[3]	1.67	0.57-4.84	0.348	1.34	0.42-4.25	0.618
Alcohol consumption[3]	3.61	1.21-10.80	0.022*	4.12	1.24-13.67	0.021*
Smoking habit[3]	3.48	1.11-10.93	0.033*	4.30	1.18-15.67	0.027*
Areas of chili farms	0.68	0.44-1.06	0.086	0.78	0.50-1.21	0.264
No. of years working in chili farming	0.97	0.92-1.03	0.298	0.96	0.90-1.02	0.181
Having other family member working on chili farms[3]	2.72	0.56-13.30	0.216	2.67	0.50-14.18	0.250
Having other crops during chili growing season[3]	1.60	0.46-5.53	0.457	1.75	0.46-6.59	0.411
Frequency of chemical fertilizer use per month[4]	2.24	0.68-7.38	0.186	5.04	1.04-24.56	0.045*
Using gloves and masks while working with chemical fertilizers[5]	1.74	0.51-5.99	0.378	2.09	0.55-7.91	0.267

OR = odds ratio; 95% CI = 95% Confidence interval; † Adjusted for having respiratory and dermal symptoms related to pesticide exposure, alcohol consumption, and smoking habit; * Significant at *p-value* < 0.05 (2-tailed); [1] 0 = female, 1 = male; [2] 0 = primary, 1= secondary or higher; [3] 0 = no, 1 = yes; [4] 0 = 1-3 times per month, 1 = more than 3 times per month; [5] 0 = always, 1= never or sometimes

CI: 1.04 - 24.56), alcohol consumption (OR_{adjust} = 4.12, 95% CI: 1.24-13.67), and smoking habit (OR_{adjust} = 4.30, 95% CI: 1.18-15.67) after adjusting for confounders such as having respiratory or dermal symptoms related to pesticide exposure, alcohol consumption, and smoking habit (Table 4).

DISCUSSION

The findings revealed that chili farmers in Hau Reua sub-district regularly used a variety of fertilizers in their farms to increase crop production with high frequency of chemical fertilizer use in a range of 1-10 times per month. The common chemical fertilizers used were NPK fertilizer (formula 15-15-15) and urea fertilizer (formula 46-0-0). Since the Thai government policy has promoted the use of chemical fertilizers as an operative mean for increasing agricultural production, so Thai farmers have increased chemical fertilizer use at high rates without standard safety procedures leading to environmental and health effects [12]. Previous studies conducted in this sub-district highlighted that farmers in this agricultural area extensively used fertilizers longer than 30 years ago contributing to heavy metal contamination in groundwater. In particular, groundwater in the areas with high intensity of chili farms was detected high concentrations of Cu, Zn, and Pb compared with other surrounding areas [17, 18].

Improper behaviors regarding chemical fertilizer use were found in chili farmers such as handling chemical fertilizers with bare hands, no personal protective equipment, and washing hands with soap and water after working with chemical fertilizers sometimes. These poor behaviors might increase risks of chemical fertilizer exposure through dermal and inhalation route as well as ingestion that might be occurred when dirty hands directly contracted mouths or contaminated food possibly contributing to health effects in chili farmers. This might be because of insufficient knowledge on chemical fertilizer risks and importance of using personal protective equipment.

However, this study found that most of chili farmers had good behaviors regarding chemical fertilizer use and found low prevalence of symptoms related to chemical fertilizers. It might presume that using personal protective equipment and washing hands with soap and water could help in preventing and reducing chemical fertilizer exposure resulting in low prevalence of symptoms. Additionally, this study revealed that the most reported symptoms from chemical fertilizer exposure were cough or sneeze, skin irritation or itching and rashes. Nonetheless, the mechanism in the development of acute health symptoms related to chemical fertilizer exposure is unknown. It might be resulted from the ingredients of chemical fertilizers contained acid substances (e.g. ammonium sulfate), alkali substances (e.g. ammonium phosphate, urea), and

dust that can irritate or damage skin and respiratory tracts causing acute health effects [22, 23]. Furthermore, repeated exposure to chemical fertilizers may contribute to the development of long-term health effects in chili farmers; so this issue should be concerned.

Moreover, this study found that chili farmers commonly used chicken and cattle manures as fertilizers; so they might get adverse health effects caused by these organic fertilizers due to many pathogens in animal manures such as bacteria, parasites, viruses [24, 25]. For example, potential zoonotic diseases from poultry to humans are Salmonellosis, Tetanus, Candidiasis, Dermatophytosis, Dermatitis, Cryptosporidiosis, Avian influenza, Newcastle disease [22, 23]. Therefore, health effects on using animal manures as fertilizers among farmers should be studied further.

According to our interviews, it found that all chili farmers directly involved in pesticide application (e.g. mixing, loading, and spraying). In addition, 39.5% of chili farmers had some respiratory and dermal symptoms (e.g. cough, skin itching, rashes) within 48 hours while working with pesticides during 2 past months; and these symptoms were familiar with the symptoms from chemical fertilizer exposure. Therefore, binary logistic regression analyses were adjusted for potential confounders such as having respiratory and dermal symptoms related to pesticide exposure, alcohol consumption, and smoking habit. The findings indicated that the frequency of chemical fertilizer use per month was a risk factor of acute health effects related to chemical fertilizer exposure after adjusting for confounders (OR_{adjust} = 5.04, 95% CI: 1.04 - 24.56). In details, chili farmers who used chemical fertilizers more than 3 times per month had 5.04 times the odds of having acute health effects compared to those who used 1-3 times per month. This might be because increasing the frequency of chemical fertilizer use linked to an increase in the frequency and dose of chemical fertilizer exposure resulting in acute health effects. A recent study conducted in rural Beijing, China demonstrated that exposure to chemical fertilizers had a significant association with increased risks of respiratory symptoms (e.g. nocturnal cough, chest tightness, chronic phlegm, wheeze) found in villagers occupationally exposed to fertilizers containing urea [8]. However, there was no report regarding the association between chemical fertilizer use and respiratory or dermal symptoms. Our findings were also found that alcohol consumption and smoking habit had a significant association with higher odds of having acute health effects related to chemical fertilizer exposure (OR_{adjust} = 4.12, 95% CI: 1.24-13.67 and OR_{adjust}=4.30, 95% CI: 1.18-15.67, respectively). Several studies have reported that alcohol consumption can directly cause or exacerbate skin manifestations and diseases (e.g. itching, urticaria, psoriasis) [26, 27]. It also links to respiratory symptoms and diseases (e.g. chronic cough, chronic phlegm, and chronic obstructive pulmonary disease) [28, 29] . Similarly, due to cigarette smoke consisted of a complex mixture of gaseous and particulate chemical compounds, smoking cigarettes cans contribute to a variety of respiratory and skin problems (e.g. asthma, chronic obstructive pulmonary disease, lung cancer, psoriasis, skin cancer) [30-32]. In fact, it is difficult to determine a certain cause of acute health effects related to chemical fertilizer exposure that is from a single cause of using chemical fertilizers or from combined causes of these three factors. Therefore, more additional studies are needed to prove the findings.

Several limitations were found in this study. First, evidences of acute health effects related to chemical fertilizer exposure were relied on self-report without medical examinations. Second, this study did not evaluate the amount of chemical fertilizer use and the exposure level of chemical fertilizers. Third, there were few sample subjects with purposive sampling; so the findings should be considered in application due to selection bias. It would be desirable to address measurement of chemical fertilizer exposure, physical examinations, and clinical interviews in future study.

CONCLUSION

To our best knowledge, this study is the first study regarding chemical fertilizer use and acute health effects in Thai farmers. It concluded that chili farmers regularly used a variety of fertilizers in their farms linking to increase risks of chemical fertilizer exposure due to their improper behaviors on chemical fertilizer use. Our findings demonstrated a low prevalence of acute health effects related to chemical fertilizer exposure among chili farmers. The frequency of chemical fertilizer use per month, alcohol consumption, and smoking habit were indicated as significant factors of acute health effects related to chemical fertilizer exposure. This study suggests that chili farmers should concern

about the safty use of chemical fertilizers to prevent health risks of chemical fertilizer exposure. Additional study is needed to further investigate acute and long-term health effects of chemical fertilizer exposure.

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