

Original Article

Differences among Thai Agricultural Workers' Health, Working Conditions, and Pesticide Use by Farm Type

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Abstract

More than 11 million Thai people (38%) work in agriculture, but since most are in the informal sector, government enforcement and support are very limited. As a result, working conditions on Thai farms vary greatly, putting the health of many agricultural workers at risk. A cross-sectional study in three Thai provinces collected information on the work activities and conditions of 424 farmers representing five farm types: rice, vegetable, flower, rice/vegetable, and flower/vegetable. The agricultural workers were mainly women (60%); their average age was 53 but ranged from 18 to 87 years. More than 64% worked more than 5 days/week. Seventy-four percent of them had only primary school education. A number of the health and hazardous working conditions surveyed were significantly different by farm type. Rice farmers were found to have the highest prevalence of allergies, nasal congestion, wheezing, and acute symptoms after pesticide use, while flower farmers had the lowest prevalence of these health outcomes. Rice farmers reported the highest prevalence of hazardous working conditions including high noise levels, working on slippery surfaces, sitting or standing on a vibrating machine, spills of chemicals/pesticides, and sharp injuries. The lowest prevalence of these working conditions (except noise) was reported by flower farmers. Vegetable farmers reported

the highest prevalence knee problems, while rice farmers had the lowest prevalence. Among these farmers, more than 27 different types of pesticides were reported in use during the past year, with the majority reporting use once a month. The flower/vegetable farming group reported the highest frequency of good exposure prevention practices during pesticide use. They were the most likely to report using cotton or rubber gloves or a disposable paper masks during insecticide spraying. Those farmers who only grew vegetables had the lowest frequency of good exposure prevention practices, including use of personal protective equipment. The economic cost of work-related injuries and illnesses among informal sector agricultural workers in Thailand is unknown and in need of study. Gaps in the regulations covering pesticide sales allow farmers to purchase pesticides without adequate training in their safe use. Training targeted to farm type regarding safe pesticide use and the prevention of accidents and musculoskeletal disorders is needed. Studies of chronic health effects among Thai farmers are needed, with special emphasis on respiratory, metabolic disease and cancer.

Keywords: agricultural workers; flower farmers; musculoskeletal disorders; pesticides; rice farmers; safety; vegetable farmers

Introduction

International Labor Office estimates that there are more than 1.3 billion agricultural workers worldwide, 60% in developing countries (International Labour Office, 2015). In Thailand, approximately 47% of the land is used for agriculture (National Statistical Office, Ministry of Information and Communication Technology, 2012) and 38% of the population (11.4 million) is engaged in agriculture (National Statistical Office, 2015). Agricultural work can be very dangerous, resulting in 24.4 fatal injuries for every 100 000 in the USA (Bureau of Labor Statistics, United States Department of Labor, 2011). However, statistics on farm injury deaths are not available in Thailand. In addition, farmers are exposed to intense sun, chemical hazards, and biological hazards, and must do a variety of repetitive work tasks in stressful working postures. Exposure to pesticides and other agrochemicals can result in acute poisoning, as well as chronic diseases including cancer (International Labour Office, 2015). This is of particular concern as the volume of pesticides imported into Thailand continues to increase (Office of Agricultural Economics, Ministry of Agricultural and Cooperatives, 2015). Thailand was ranked the fourth in annual pesticide consumption worldwide (Pretty and Bharucha, 2015). Thailand imported 149 458.69 tons of pesticide, including 119 971.88 tons of herbicide, 12 927.52 tons of insecticide, and 11 088.37 tons of fungicide in 2015. The number of pesticide poisoning cases was 10 177 for the whole country (a rate of 17 cases per 100 000 population). The highest rate was 131 in Sakon Nakhon Province in the Northeast of Thailand (Bureau of Occupational and Environmental Diseases, Center for Disease Control, Ministry of Public Health, 2015). The Ministry of Labour has a regulation to protect agricultural workers;

however, it only covers agricultural workers who are employees and who are employed all year round in cultivation. The focus of the regulation is wages and benefits, not health and safety (Tajgman, 2014). However, Thai farm owners generally do not hire workers for 180 continuous days, so many of these provisions are irrelevant (Kongtip *et al.*, 2015). Self-employed agricultural workers and those who work in the informal agricultural sector are covered by a guidance document from the Department of Labour Protection and Welfare (Ministry of Labor, 2013). This guidance encourages all informal workers, including self-employed persons, to take care of their workplaces in order to promote safety and health at work and to meet applicable standards. However, currently there is no administrative structure for the effective administration of this notification or any provision of occupational safety and health services or consultation to informal sector agricultural workers to aid them in improving their working conditions.

Most of the research on agricultural workers in Thailand has been limited to one group of agricultural workers growing one kind of crop or in one geographic area (Panuwet *et al.*, 2008; Kachaiyaphum *et al.*, 2010; Prasertsung, 2012; Kaewboonchoo *et al.*, 2015). For example, in Sukkhothai Province, 420 rice farmers who applied pesticide were studied and their symptoms reported after pesticide spraying (Phataraphon and Chapman, 2010). Likewise, chili (Kachaiyaphum *et al.*, 2010) and vegetable farmers (Kongtip *et al.*, 2011) using pesticides have been studied in Thailand. One survey in Pathumthani Province looked more broadly at hazardous working conditions, pesticide symptoms and injuries among rice farmers ($n = 968$) (Buranatreveth and Sweatsriskul, 2005). However, this study is unique in that we compare the demographics, working conditions,

chronic health conditions, and acute health impacts of agricultural work and preventative occupational health behaviors across five different types of Thai agricultural workers, as defined by the types of crops they grow.

Materials and methods

Agricultural workers from three areas of Thailand were recruited into the study. They included the provinces of Nakorn Ratchasima in the northeastern, Phisanulok province in the lower north, and Payao province in upper north of Thailand. Recruitment was done through health-promoting hospitals (small local primary care clinics) in subdistricts within the province. Originally we planned for about 150 rice, vegetable, and flower farmers, but we found that many farmers raised more than one crop following the sufficiency economy of the late King of Thailand (Ministry of Foreign Affairs, Kingdom of Thailand, 2015). Therefore, farmers were categorized as growing one of five types of crops: rice, flowers, vegetables, a mixture of rice/vegetables, or a mixture of flowers/vegetables. The sample collection was performed during August 2013 to February 2014. A group of researchers with a range of expertise put the questionnaire together. The musculoskeletal disorder (MSD) questionnaire was adapted from a risk evaluation of MSD symptoms prepared by Bureau of Occupational and Environmental Diseases (Bureau of Occupational and Environmental Disease, Center for Disease Control, 2015). The health symptoms after pesticide use and health behaviors of agricultural workers while working with pesticides were adapted from the manual for the Occupational Health Service Agricultural Health Clinics (Bureau of Occupational and Environmental Diseases, Center for Disease Control, 2015). We revised the questionnaire after piloting for clarity with agricultural workers, most of whom have a primary school education. Farmers were invited to come to the local clinic where trained research teams performed face-to-face interviews with the subjects. If they could not come, the research team went to their home or farm to interview them. The farmers were asked a questionnaire that consisted of four sections: general demographic information along with farm characteristics and activities; health information related to chronic and acute diseases including MSDs; general working conditions including chemical, biological, physical, and ergonomic hazards; and specific information about agricultural hazards, pesticide use, and pesticide exposure prevention behaviors. The questionnaire is available in Thai at <https://www.geohealthseasia.org/resources>. This study was approved by the Faculty of Public Health, Mahidol University Institutional Review Board.

Data analysis

Descriptive statistics were calculated using SPSS (version 18; PASW Statistics Base 18). Since some data were highly skewed, concentrations were reported as the median, range, or interquartile range (IQR). Testing to compare the five types of agricultural workers was conducted using contingency tables and the Fisher's exact test.

Results

Characteristics of agricultural workers

The characteristics of the agricultural workers in this study varied by farm type (Table 1). Most agricultural workers in this study were women (60%). However, there were significant differences across farming types, with vegetable farmers more likely to be women (69%) and rice farmers less likely (50%). The average age of all farmers was 53 years, with a range of 18–87 years. Seventy-five percent had only a primary school education. Flower and vegetable farmers had smaller farm lands (median 0.3–0.8 hectare), while rice farms were larger (median 4 hectares). Most agricultural workers were the owners of their farms. The majority of farmers (66%) worked 8–10 hours per day although there was a significant difference in the number of hours worked by farm type, with rice or rice/vegetable farmers reporting fewer percentages. More than 64% worked more than 5 days/week.

The most common activities reported by farmers were controlling weeds (80%) and applying pesticides (74%), while the least common activities were driving a truck or other farm equipment (37%) and digging soil (44%) (Table 1). The frequency with which farmers reported conducting these activities varied significantly by farm type. For example, flower farmers were least likely to report digging soil (1%) or sorting, bagging or packaging crops (38%), while rice/vegetable farmers were most likely to report digging (80%) or sorting, bagging, or packaging crops (70%). Rice farmers were most likely to report applying pesticides (84%), while flower farmers were least likely (61%).

Most rice farmers grew rice all year round, if there was enough water available from rain or from irrigation systems. All rice farmers grew rice in open fields, with 46% using farm equipment in plowing and other tasks. Most (84%) applied pesticides to protect their crops, using a variety of insecticides, herbicides, and fungicides with a range of frequencies (see Table 1 in the Online Supplementary Material, available at *Annals of Work Exposures and Health* online). The equipment used for spraying pesticides was typically backpack spraying (80%) or truck spraying (20%).

Table 1. Comparison of agricultural workers demographics and activities by farm type (n = 424).

Demographics and activities (% reporting unless otherwise specified)	Rice farmers (n=44)	Flower farmers (n=77)	Vegetable farmers (n=165)	Rice and vegetable farmers (n=70)	Flower and vegetable farmers (n=68)	Average	Fisher's exact test P-value
Sex							
Male (%)	22 (50)	31 (40.3)	51 (30.9)	30 (42.9)	35 (51.5)	39.9	0.022*
Female (%)	22 (50)	46 (59.7)	114 (69.1)	40 (57.1)	33 (48.5)	60.1	
Mean age (SD)	50.1 (11.2)	56.4 (9.4)	52.3 (13.1)	50.6 (13.7)	53.0 (9.8)		
(Min–max) (year)	23–67	30–76	21–87	18–84	24–72		
Education							
≤Primary school (%)	68.2	77.9	75.2	74.3	76.5	75.0	0.837
Agricultural area (Hecta)							
Median (IQR)	4	0.3	0.8	3	0.3		
Min–max	0.5–12.8	0–8	0–8	0.04–16	0–1.1		
Employment status							
Owner	68.2	74	78.7	87.1	83.8	78.8	0.091
Employed	29.5	26	21.3	12.8	14.7	20.5	0.108
Rented	2.3	0	0	0	1.5	0.47	0.129
No. hour/day work							
<8 hours	46.2	24.2	35.7	40.4	16.2	31.4	0.002*
8–10 hours	53.6	75.8	64.2	59.6	83.9	65.8	
No. days/week work							
<5	10.3	36.6	11.4	2.9	28.1	16.3	<0.001*
≥5	89.7	63.5	88.7	97.1	72	77.6	
What agricultural activities do you do on your farm?							
Dig the soil	61.4	1.3	60	80	0	43.6	<0.001*
Grow plants	90.9	42.9	84.8	94.3	46.3	72.9	<0.001*
Control weeds	81.8	77.9	82.9	74.3	82.1	80	0.593
Sort, bag, or package crops	45.5	37.7	65.2	70	59.7	57.8	<0.001*
Hand pick crops or plants or flowers	54.5	19.5	81.7	91.4	23.9	59.7	<0.001*
Apply chemical fertilizer or manure	77.3	58.4	64.6	72.9	80.6	68.4	0.021*
Apply pesticides	84.1	61	75.6	80	71.6	73.6	0.029*
Drive truck or other farm equipment	45.5	39	23.5	41.4	59.7	37.0	<0.001*

*Significant at $P < 0.05$.

Most flower farmers (91%) grew flowers in the rainy season (July to October) although some (21%) also grew in the winter season (November to February) and a few (13%) in the hot season (March to June). Although a majority reported applying pesticides, the frequency of pesticide application and type varied (see [Table 1](#) in the

Online [Supplementary Material](#), available at *Annals of Work Exposures and Health* online), as did the method of application. Common application methods reported by these farmers included backpack spraying (69%), truck spraying (21%), hand pouring (10%), and boat spraying (8%).

Most vegetable farmers grew vegetables all year round, with 70% growing in an open field where they used different types of insecticides, herbicides, and fungicides with a range of frequencies throughout the growing cycle (see [Table 1](#) in the Online [Supplementary Material](#), available at *Annals of Work Exposures and Health* online). Like flower farmers they reported using a variety of equipment to apply the pesticides including backpack spraying (87%), truck spraying (10%), bucket pouring (15%), and boat spraying (2%).

Most farmers (88%) who grew both rice and vegetables farmed all year round. If their farmlands were near an irrigation system or rivers, they could grow both rice and vegetables all year. If their farmlands did not have a sufficient water supply, they grew rice only once a year in the rainy season, but they grew vegetables all year round. The pattern of insecticide, fungicide, and herbicide use was more like rice farmers than vegetable farmers (see [Table 1](#) in the Online [Supplementary Material](#), available at *Annals of Work Exposures and Health* online). Like other farmers they sprayed pesticides most commonly using a backpack sprayer (78%), but also reported using truck spraying (3%), bucket pouring (6%), and other methods (8%).

Farmers who grew both flowers and vegetables farmed all year round. They reported farming most frequently in the rainy season (85%), followed by winter (39%) and summer seasons (26%). These farmers reported a high percentage of uncategorized types of insecticides (see [Table 1](#) in the Online [Supplementary Material](#), available at *Annals of Work Exposures and Health* online), but used similar spraying methods to other farmers: backpack spraying (87%), truck spraying (10%), bucket pouring (15%), and boat spraying (2%).

Health conditions

The overall prevalence of self-reported chronic health problems among these Thai agricultural workers was found to be: asthma 3%; allergy 4%; diabetes 7%; high blood pressure 24%; heart disease 3%; cancer 1%; thalassemia 0.5%; hypercholesterolemia 7%; thyroid disease 3%; and arthritis 5%. For underlying chronic conditions, there were only two diseases that had significant differences by farm type ([Table 2](#)). There was a higher percentage of rice farmers (9%), and a lower percentage of flower farmers (1%) reporting allergy than other farmers. Also a higher percentage of flower farmers (27%) and a lower percentage of rice farmers (18%) reported high blood pressure than other farmers.

With regard to other health problems reported during the past 3 months, significant differences were found for several symptoms ([Table 2](#)). As with chronic allergies,

nasal congestion and runny nose were significantly different among the farm types with a higher percentage of rice farmers reporting nasal congestion (44%), and a lower percentage of flower farmers (23%). Likewise, wheezing was significantly different among the farm types with a higher percentage of rice farmers reporting wheezing (26%) and a lower percentage of vegetable/rice farmers (6%). Headache was reported most often by vegetable farmers (55%).

Symptom reports by farmers in the past 3 months after they used pesticides included dizziness 26%, nausea/vomiting 13.4%, blurry vision 23%, cramps 17%, and sweating 34%. Several symptoms were significantly different by farm type; dizziness, nausea/vomiting, and sweating were reported most frequently by rice farmers and least frequently by flower farmers ([Table 3](#)).

Working conditions

Among these Thai agricultural workers, the overall prevalence of self-reported hazardous working conditions was high background noise level (19%), moving heavy materials >20 kg by lifting, pushing, pulling (66%), twisting the body or stooping while sitting or standing most of the time (85%), using fingers, hands, and arm in a continuous abnormal posture (including twisting of the wrist) (75%), using hands or fingers to work with a machine or tool (e.g. using machine to plow the soil) (62%), sitting or standing on a vibrating machine (such as a tractor or harvester) (34%), squatting or kneeling to work most of the time (64%), and working on slippery surface (47%).

A number of working conditions varied significantly by farm type ([Table 4](#)). Among these, rice farmers had the highest percentage reporting high noise exposures (39%) and working on slippery surfaces (60%). Rice/vegetable farmers (83%) and rice farmers (82%) had the highest percentage reporting use of fingers or hands to work with machines or tools. Flower farmers had the lowest percentage reporting sitting or standing on a vibrating machine such as a tractor (17%) and rice farmers the highest (55%). Vegetable farmers had the highest percentage who reported sitting on the ground most of the time (56%), while rice farmers reported the lowest percentage (32%). Squatting to work most of the time was least commonly reported by flower/vegetable farmers (44%).

Musculoskeletal disorders

When asked to report on MSD symptoms in the past 3 months, these agricultural workers reported a prevalence of neck 13%, both shoulders 11%, fingers 8%, upper back 14%, lower back 22%, hip/thigh 19%, and

Table 2. Underlying chronic health conditions and health problems of agricultural workers in the past 3 months by farm type.

Health condition (% reporting)	Rice farmers (n=44)	Flower farmers (n=77)	Vegetable farmers (n=165)	Rice and vegetable farmers (n=70)	Flower and vegetable farmers (n=68)	Average	Fisher's exact test <i>P</i> -value
Asthma	2.3	1.3	3.0	2.8	2.9	2.6	0.344
Allergy	9.1	1.3	2.4	4.3	5.9	3.8	0.016*
Diabetes	4.5	6.5	6.1	10.0	7.4	6.8	0.155
High blood pressure	18.2	27.3	23.6	22.8	26.5	24	0.005*
Heart disease	–	6.5	1.8	–	7.4	3.1	0.497
Cancer	2.3	–	0.6	1.4	4.4	1.4	0.161
Thalassemia	–	1.3	–	–	1.5	0.5	0.693
Hypercholesterol	4.5	10.4	8.5	2.8	4.4	6.8	0.248
Thyroid disease	2.3	5.2	3.0	2.8	2.9	3.3	0.984
Arthritis	–	11.7	3.6	1.4	7.4	5	0.159
Respiratory tract							
Nasal congestion, runny nose	44.2	23.4	37.8	39.7	23.5	33.5	0.024*
Cough/Cough with phlegm	46.5	28.6	38.4	32.9	36.8	36.1	0.329
Chest tightness	30.2	26.0	21.5	20	25	23.4	0.684
Wheezing	25.6	11.7	11.7	5.7	17.6	13.1	0.027*
Other symptoms							
Headache	40.9	37.7	54.9	41.4	35.3	44.6	0.023*
Dizziness	46.5	42.9	57.9	47.1	39.7	49.1	0.063
Mild fever	23.3	16.9	18.5	24.3	8.8	17.9	0.157
Loss of appetite/ Weight loss	32.6	10.4	26.4	26.1	11.8	21.5	0.004*
Blurry vision	35.7	51.3	51.5	34.3	41.2	44.8	0.058
Eye irritation/red eye/eye watery	32.6	31.2	24.8	35.7	27.9	28.8	0.501
Itchy	29.5	26	34.1	32.4	35.3	31.8	0.719
Rash	11.6	20.8	23.9	19.1	32.4	22.4	0.115

*Significant at $P < 0.05$.**Table 3.** Agricultural worker health symptoms after using pesticides in the past 3 months by farm type.

Health symptoms (% reporting)	Rice farmers (n=44)	Flower farmers (n=77)	Vegetable farmers (n=165)	Rice and vegetable farmers (n=70)	Flower and vegetable farmers (n=68)	Average	Fisher's exact test <i>P</i> -value
Dizziness	43.2	18.2	23.6	34.3	20.6	25.9	0.001*
Salivation	6.8	3.9	5.5	4.3	5.9	5.2	0.752
Nausea/vomiting	20.5	7.8	15.8	14.3	8.8	13.4	0.021*
Numbness	9.1	10.4	19.4	17.1	16.2	15.8	0.055
Blurry vision	25	16.9	26.7	21.4	22.1	23.1	0.073
Cramping	15.9	15.6	17	21.4	11.8	16.5	0.055
Sweating	40.9	24.7	34.5	42.9	30.9	34.2	0.007*
Unsteady walk	–	5.2	12.1	7.1	1.5	7.1	0.001*
Unconsciousness	–	1.3	1.2	–	–	0.7	0.781
Depression	4.5	0.2	7.3	2.9	1.5	5.0	0.167

*Significant at $P < 0.05$.

Table 4. Working conditions for agricultural workers in the past 3 months by farm type.

Working conditions (% reporting)	Rice farmers (n=44)	Flower farmers (n=77)	Vegetable farmers (n=165)	Rice and vegetable farmers (n=70)	Flower and veg- etable farmers (n=68)	Average	Fisher exact test <i>P</i> -value
High background noise level	38.6	20.8	16.4	16.1	16.2	19.1	0.015*
Moving heavy materials >20 kg by lifting, pushing, and pulling	79.1	61.1	67.7	72.8	55.9	66.3	0.064
Twist the body or stoop while sitting or standing most of the time	95.5	80.6	84.9	89.9	77.9	84.7	0.065
Using fingers, hands, and arm in a continuous abnormal posture (including twisting the wrist)	74.4	72.8	74.6	71.4	80.9	74.5	0.748
Using hand or fingers to work with a machine or tool (e.g. cut branch of tree using small tool, machine to plow the soil)	81.9	48.1	59.8	82.6	50	61.8	<0.001*
Sitting or standing on a vibrating machine such as a tractor or harvester	54.7	16.9	31.6	52.9	32.4	34.4	<0.001*
Sitting on the ground most of the time to work	31.8	46.8	55.8	42	44.2	47.4	0.040*
Squatting or kneel most of the time to work	63.7	52	65.8	68.6	44.1	63.9	<0.001*
Standing most of the time	52.3	74.1	58.8	52.9	55.9	59.4	0.052
Working on slippery surface	60.4	35.4	55.2	54.4	28	47.4	<0.001*

*Significant at $P < 0.05$.

both knees 15%. The only significant difference in MSD symptoms by farm type was for knees, where the lowest frequency was among rice farmers (2%), while vegetable farmers had the highest frequency (19%) (Fig. 1).

Accidents

A large percentage (31%) of these Thai farmers reported having a spill of chemicals or pesticides onto the body or into the eyes in the past 3 months. Other accidents that were reported frequently were cuts from sharp objects (23%); falls on slippery surfaces (22%); and being hurt by toxic animals, such as snake and insects (24%). There were significant differences in the reports of chemical/pesticide spills to the body or

in the eyes by farm type, with rice farmers having the highest frequency of reporting (50%) and flower farmers the lowest (14%) (Fig. 2). Likewise, rice farmers reported the highest frequency of injuries from sharp objects (33%), while flower farmers reported the lowest frequency (13%).

Exposure prevention behaviors during the use of pesticides

When spraying insecticides during the rainy season (the season of most agricultural production and insect infestation), most of these Thai agricultural workers reported wearing long pants (56%), long sleeve shirts (75%), boots (68%), a cloth wrapped around their

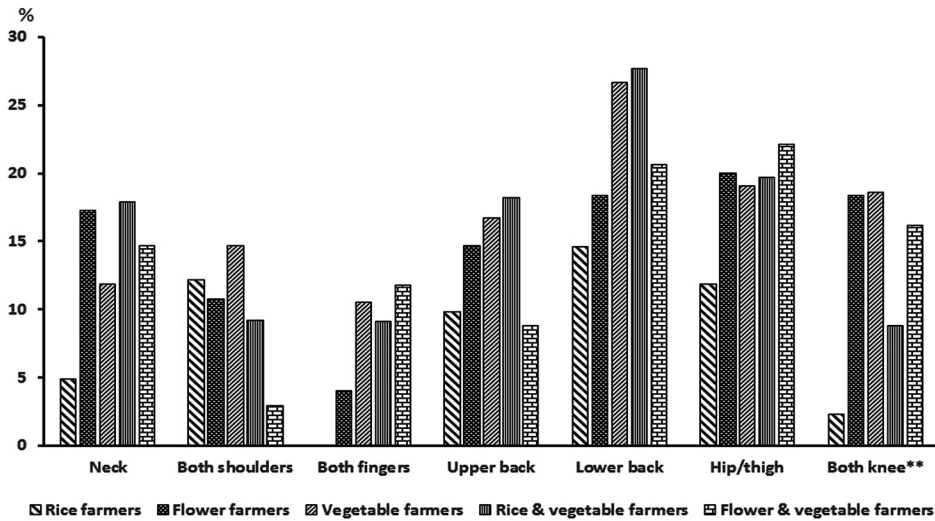


Figure 1. Musculoskeletal disorders in the past 3 months by farm type (**significant differences at $P < 0.05$).



Figure 2. Accidents in the past 3 months by farm type (**significant differences at $P < 0.05$).

face (74%), and rubber gloves (55%). Less than half reported wearing cotton gloves (34%), a balaclava (39%), a disposable paper mask (35%), or goggles (17%). There were significant differences in personal protective equipment (PPE) use while spraying insecticides by farm type. For the use of rubber and cotton gloves, the highest frequency of use was reported by flower and flower/vegetable farmers compared with vegetable farmers, who reported using the least (Fig. 3).

A high percentage of flower and flower/vegetable farmers reported use of disposable paper masks compared with rice and vegetable farmers who reported using the least.

The behavior of agricultural workers while spraying pesticides was classified into positive and negative pesticide exposure prevention behaviors. Most of the farmers in this study reported always using a range of good pesticide exposure prevention practices; 60% reported

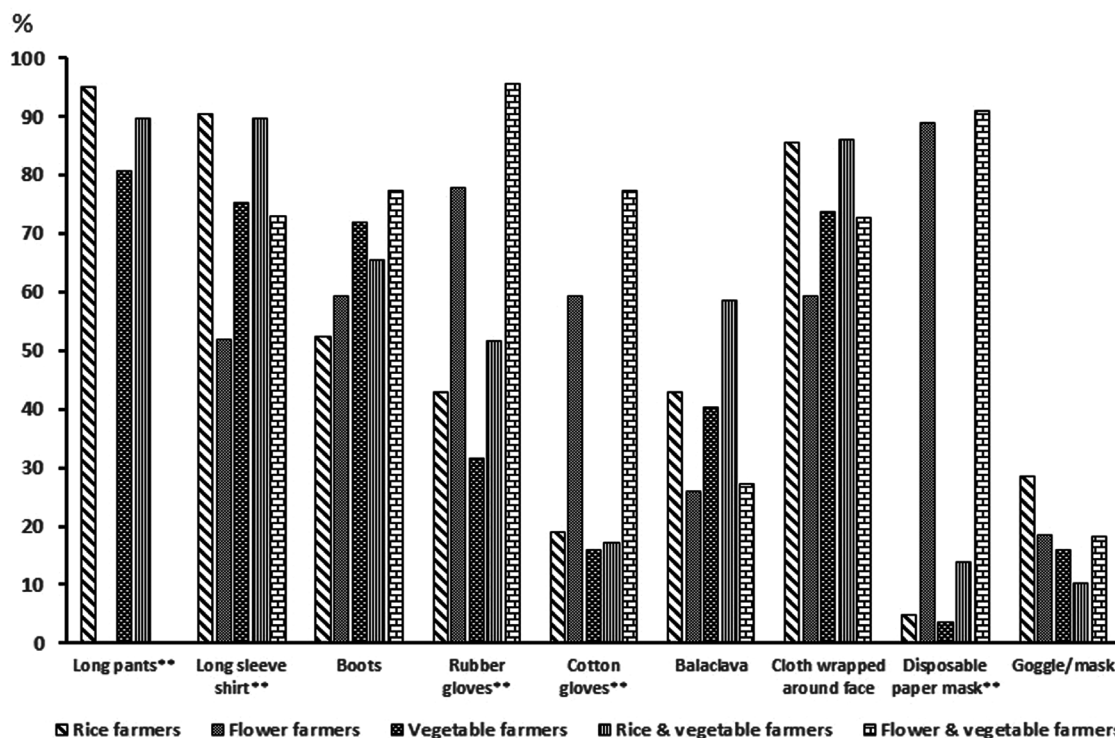


Figure 3. Personal protective equipment use during insecticide spraying in the rainy season by farm type (**significant differences at $P < 0.05$).

reading the label before using; 57% reported taking a bath after being soaked by pesticides; 65% reported always washing their hands before eating or drinking; 63% reported changing their contaminated clothing after spraying; 63% reported taking a bath after spraying and; 63% reported separating contaminated clothing from normal clothing when washing. When comparing the farming types, the flower/vegetable farming group reported the highest frequency of these good exposure prevention practices in all areas except “Before using a new pesticide bottle, you read the label,” a practice where the rice/vegetable farmer group reported the highest frequency (71%). The vegetable farmers had the lowest frequency for all of the positive exposure prevention behaviors, except reading the label before using a pesticide (flower farmers reported the lowest frequency of 53%) (Table 5).

For the poor exposure prevention practices, most of these farmers reported never using poor pesticide exposure prevention practices; 91% reported never smoking cigarettes while spraying pesticide; and 86% reported never eating/drinking food/beverage while spraying pesticide.

Discussion

Characteristics of Thai agricultural workers

There has been a transition in the population engaged in agriculture in Thailand. Increasingly young people are leaving the rural areas and migrating to the cities to get industrial or service sector jobs. They return to help with the agricultural work on the family farm when needed. Interestingly, 9% of flower farmers and 11% of vegetable farmers receive health benefits through government employee health coverage. They could either be retired government employees or, more likely, their adult children are government employees and they receive coverage through them. The average age of the farmers in this study was 53. Thus, many may be grandparents who have remained engaged in farming, often with the help of some of their children who have remained in the rural area, as well as the grandchildren that they frequently take care of while parents work in the city. In 1987, 35% of those aged 15–24 years were agricultural workers, while in 2007 the percentage had decreased to 12%. However, for those aged 40–59 years the percentage in agricultural work increased from 26% in 1987 to 46% in 2011, while among those over age 60, the percentage in agricultural

Table 5. Exposure prevention practices of agricultural workers while using pesticides by farm type.

Exposure prevention practices (% reporting)	Rice farmers (n=44)	Flower farmers (n=77)	Vegetable farmers (n=165)	Rice and vegetable farmers (n=70)	Flower and vegetable farmers (n=68)	Average	Fisher's exact test <i>P</i> -value
Good exposure prevention practices	Always	Always	Always	Always	Always		Always
1. Before using a new pesticide bottle, you read the label	27 (61.4)	41 (53.2)	97 (58.8)	50 (71.4)	40 (58.8)	60.1	0.285
2. When your clothes are soaked with the chemical do you take a bath or clean the contaminated skin immediately?	25 (56.8)	51 (66.2)	77 (46.7)	42 (60)	45 (66.2)	56.6	<0.001*
3. Always wash hands before eating or drinking	28 (63.6)	52 (67.5)	101 (61.2)	46 (65.7)	50 (73.5)	65.3	0.002*
4. Do you change contaminated clothes immediately after spraying?	29 (65.9)	49 (63.6)	98 (59.4)	46 (65.7)	47 (69.1)	63.4	0.030*
5. Do you take a bath immediately after spraying?	28 (63.6)	51 (66.2)	97 (58.8)	46 (65.7)	47 (85.5)	63.4	0.016*
6. Do you wash your clothes contaminated with chemicals separately from other clothes?	29 (65.9)	50 (64.9)	93 (56.4)	46 (65.7)	48 (70.6)	62.7	0.003*
Poor exposure prevention practices	Never	Never	Never	Never	Never		Never
1. While spraying pesticides, do you smoke cigarettes?	42 (95.5)	68 (88.3)	154 (93.3)	66 (94.3)	54 (79.4)	90.6	0.823
2. While spraying pesticides, do you eat/drink food/beverage?	38 (86.4)	64 (83.1)	152 (92.1)	61 (87.1)	49 (72.1)	85.8	0.100

*Significant differences at $P < 0.05$.

work tripled from 4% in 1987 to 13% in 2011 (Tonsri, 2014). This demographic shift has occurred as Thailand has become more industrialized and young people discover that the hard work and high cost of farming produces an uncertain income due to the dependence on weather patterns and crop prices. The numbers of female and male (60:40) in Thai agricultural workers in this study were different from the report of World Bank with similar number of female and male agricultural workers in Southeast Asia in 2007 (World Bank, 2007). We postulate that we found a higher percentage of women agricultural workers due to more recent economic drivers that push more men to move to urban areas where they are hired in manufacturing or other cash economy jobs; however, it could also be that more women than men were willing to be subjects in our study.

Pesticides in Thai agriculture

Pesticide use was widespread among the farmers interviewed in this study (74% overall). Thailand continues to increase its total annual import volume of pesticides. The most common type of pesticides imported is herbicides, followed by insecticides and fungicides (Office of Agricultural economics, Ministry of Agricultural and Cooperatives, 2015). Among the pesticides reported in this study, we found a similar trend (see Table 1 in the Online Supplementary Material, available at *Annals of Work Exposures and Health* online). Among our 424 farmers, 27 pesticides were reported in use during the past year. Similarly, in a study of 202 rice, sugarcane, and vegetable farmers in Suphanburi province, 87 different brands of insecticides, 93 brands of plant hormones, and 56 brands of chemicals for the “control of

plant diseases” were reported in use (Prasertsung, 2012). We found that the majority of farmers reported use of some type of pesticide once a month. This aligns with a study by Sapbamrer and Nata (2014) that reported 78% of rice farmers in northern Thailand used pesticides one time a month or less. However, others have reported even more frequent use pesticides, with farmers reporting applications an average of 3–4 times a month (Panuwet *et al.*, 2008; Kachaiyaphum *et al.*, 2010).

The number of pesticides used by rice farmers in Thailand varied by type, with 26% of the pesticides reported classified as insecticides, 50% herbicides, and 23% fungicides. In previous work, rice farmers in Northern Thailand reported more use of insecticides (85% reported use) and herbicides (63% use) but less use of fungicides (7%) (Sapbamrer and Nata, 2014). Rice farmers in the Mekong Delta, Vietnam also reported a higher use of insecticides (50%), a lower use of herbicides (25%), and a similar use of fungicides (25%) (Berg, 2001). Thai rice farmers commonly grow rice in the rainy season when grasses and weeds grow very quickly, which may have contributed to the higher reporting of herbicide use. Insecticide use depends on the types of pests, so may vary by location and season. Rice farmers in this study did not use organophosphate (OP) insecticides; they used pyrethroids (31%) and carbamates (17%). This is different from rice farmers in Bangladesh, who were reported using eight OPs, eight carbamates, and three pyrethroid insecticides (Schilmann *et al.*, 2010). Bangladeshi farmers used mostly WHO category IA, IB, and II pesticides, which are more hazardous than the insecticides used in our study. For fungicides, rice farmers in this study used mainly propiconazole mixed with difenoconazole (50%), but the rice farmers in Bangladesh used mainly carbendazim (44%).

Flower farmers in this study reported using insecticides (24%), herbicides (65%), and fungicides (11%). Flower farmers in Mexico reported more use of insecticides (51%) and fungicides (43%), but less use of herbicides (5.7%) in the dry season as well as in the rainy season (insecticides (50%), fungicides (45%), and herbicide (5%) (Schilmann *et al.*, 2010).

Among vegetable farmers, 29% of the pesticides reported were classified as insecticides, 47% herbicides, and 24% fungicides. The vegetable farmers in this study used a considerably higher percentage of herbicides than those in the Tanzania (10%) and Ghana (6%) (Ngowi *et al.*, 2007). The reason for this difference is not clear, unless herbicides are more cost-prohibitive in Africa. Although the insecticides most commonly reported in this study were pyrethroids (19%) and carbamates (19%), Thai vegetable farmers also reported use of

beta-cyfluthrin (9%) and carbofuran (15%), both of which are classified as IB highly hazardous pesticide by WHO (World Health Organization, 2010). Vegetable farmers in Northern Tanzania also reported use of IB pesticides including methomyl insecticide, carbofuran, nematicide, and zinc phosphide rodenticides (Ngowi *et al.*, 2007).

Pesticides are regulated under the Thai Hazardous Substance Act of 1992 (last amended in 2008). Under this act, the Department of Agriculture controls the registration, production, distribution, and sale of pesticides. However, once registered, there is little or no control on the end use, sale or disposal of registered pesticides, nor are there training requirements for users. There are reported to be more than 26 000 retailers licensed to sell more than 20 000 pesticide formulations available in Thailand, and there are no restrictions on the advertising or sale of these products (Panuwet *et al.*, 2012). Recommendations to improve the regulation of pesticide sales and require mandatory training for agricultural users of pesticides have not been implemented to date (Kaewboonchoo *et al.*, 2015).

Health conditions

In this study, the prevalence of diabetes for all farm types (7%) was similar to the prevalence in the general Thai population (6.9%) (Bureau of Policy and Strategy, Ministry of Public Health, 2011) but lower than that for the Thai population age 45–59 years (10%) (Aekplakorn, 2009). For high blood pressure, this group of agricultural workers had a higher prevalence (24%) than the general Thai population (21.4%) (Bureau of Policy and Strategy, Ministry of Public Health, 2011) and the Thai population age 45–59 years (21%) (Aekplakorn, 2009). However, these workers had a lower prevalence of high cholesterol (7%) than the general Thai population age 45–59 years (59%) (Aekplakorn, 2009). In the USA, evidence of a healthy worker effect was identified for adult-onset respiratory diseases compared with the general population (Ye *et al.*, 2013; Hoppin *et al.*, 2014). However, studies of chronic disease among Thai agricultural workers have not been conducted to date.

For the health conditions reported in the past 3 months, there was concordance between the chronic health conditions and the report of symptoms in the past 3 months. Rice farmers reported the highest percentage of allergies (9.1%) and the highest frequency of nasal congestion/runny nose (44.2%) and wheezing (25.6%). One study of grape farmers in Greece found a higher prevalence of allergic rhinitis among those using pesticides than among grape farmers who did not use pesticides or controls (Chatzi *et al.*, 2007). In that study, the highest risks were among

farmers using paraquat herbicides, dithiocarbamate fungicides, and carbamate insecticides. Use of all of these pesticides was reported by rice farmers in this study (see [Table 1](#) in the Online Supplementary Material, available at *Annals of Work Exposures and Health* online).

Although there was no significant difference among the types of farms, many farmers reported skin problems such as itching (32%) or rashes (22%) in the past 3 months ([Table 2](#)). Skin problems among agricultural workers depend on many factors, including levels of solar radiation, and the frequency of contact with chemicals and plant allergens ([Brueggeman and Rosenthal, 2001](#)). The dermal conditions that were reported could be caused by exposure to plants during harvesting or when farmers are exposed to pesticides during mixing, applying, cleaning the spray equipment, or disposing of the empty pesticide bottles ([Spiewak, 2001](#)). Eye irritation/red eyes (29%) and blurry vision (45%) were also reported by farmers in this study. This was similar to the reports by seasonal and migrant farm workers who reported eye pain and redness (40%) after working all day exposed to agricultural chemicals, wind, dusts, and ultraviolet rays ([Quandt et al., 2001](#)).

A large number of farmers reported respiratory symptoms in the past 3 months, including 36% with cough/cough with phlegm, 23% with chest tightness, and 13% with wheezing. Rice farmers reported significantly more wheezing (26%) than other farmers ([Table 2](#)). Among Polish farmers working in harvesting and threshing of grain, 26% reported dry cough, 19% dyspnea, and 10% chest tightness ([Skórska et al., 1998](#)). In the USA, farmers were found to have higher prevalence of current respiratory symptoms (wheeze, cough, and phlegm) than the general population ([Hoppin et al., 2014](#)). In farming there are many exposures to respiratory hazards such as organic and inorganic dusts, chemical fertilizers and pesticides, bacteria, and fungi ([Linaker and Smedley, 2002](#)).

When comparing the health symptoms after pesticide use for all of the farmers in this study with a previous study of vegetable farmers using the OP ethion, there was a higher percentage of these study farmers who reported sweating (34% versus 18%), but a lower percentage who reported vomiting (16% versus 21%) and cramping (17% versus 43%) ([Kongtip et al., 2011](#)). This may be a result of the lower use of OPs (0.5%) and carbamates (19%) reported by the farmers in this study.

Several symptoms (dizziness, nausea/vomiting, sweating) reported after applying pesticides were highest among rice farmers and lowest among flower farmers. This is surprising because rice farmers did not report use of OP pesticides and the use of carbamate insecticides was highest among flower farmers (30%) compared with rice farmers (17%). However, it should be noted that fewer

rice farmers in this study reported common OP or carbamate exposure symptoms than in a study of rice farmers who used the OP chlorpyrifos ([Kongtip et al., 2009](#)).

MSDs and working conditions

While there were a large percentage of the agricultural workers in this study that reported moving heavy materials (66%), twisting or bending the body while sitting or standing (85%), only 22% of these farmers reported lower back and 14% reported upper back MSD symptoms in the past 3 months. Most (96%) of the rice farmers reported twisting the body or stooping while sitting or standing most of the time at work although only 10% reported upper back and 15% lower back MSD symptoms. Rice farmers have to bend to plant the rice seeds into the soil or transplant them when they reach 5–7 inches in height into the paddy fields and they also bend to harvest the rice.

There were also a large number of farmers (74%) who reported using their hands and arms in continuous abnormal postures, yet only 11% reported MSD symptoms in the shoulders and 8% reported symptoms in the fingers. Previous reports from the USA have found that 70% of farm equipment operators reported pain in one or more body parts ([Kittusamy et al., 2004](#)). Another study examined tractor driving tasks in relation to low back pain: silage chopping (significantly increased) and ploughing (not significantly increased). The authors suggest low back pain was related to long static postures while driving and the need to twist the trunk while looking backward ([Toren et al., 2002](#)). In this population, 37% of farmers reported driving a truck or farm equipment ([Table 1](#)), with the highest frequency reported among the flower/vegetable farmer group. But when asked about sitting or standing on vibrating machinery such as tractors or harvesters, the highest frequency reported was among the rice farmers (55%) and rice/vegetable farmers (53%). Although not significantly different from the other farm groups, rice/vegetable farmers also reported the highest frequency of upper back (18%) and lower back (28%) MSDs ([Fig. 1](#)). Migrant workers in the USA were also found to be vulnerable to musculoskeletal injuries due to relatively long intense workdays as farm workers. Injury/illness cases were reported over two seasons with joint/muscle strain among 31% farm workers ([Earle-Richardson et al., 2003](#)).

The MSD symptom in this study that varied significantly by type of farm was knee symptom. This was likely driven by the low percentage of rice farmers with knee symptoms (2%) although 16% of rice/vegetable farmers reported knee symptoms. The highest percentages of agricultural workers reporting most of the time squatting or kneeling to work were rice/vegetable

farmers (69%), vegetable farmers (66%), and rice farmers (64%). High knee stress could occur when the knee was flexed during long static postures such as squatting to pick weeds or crops. Kneeling could also create contact stresses that may lead to knee discomfort and disorders (National Institute for Occupational Safety and Health, 2001). A study of farmers in Bangladesh found that 48% reported knee pain and that their MSD pain was more common when they worked in squatting position (52%), especially during the weeding of plants (31%) (Basher *et al.*, 2015).

Accidents

Although (31%) of farmers reported having a spill of chemicals or pesticides on the body or in the eyes in the past 3 months, there were significant differences among farm types, with rice farmers having highest reporting rate (50%) and flower farmers the lowest (14%) (Fig. 2). This aligns with their reported farm activities, where rice farmers were most likely to report applying pesticides (84%), while flower farmers were least likely (61%) (Table 1).

Although sharps injuries were also a highly reported accident in this cohort, the overall percentage of agricultural workers reporting cuts from sharp objects (23%) was lower than that reported in a 2011 survey of the general health status of Thai labor where the major health problems reported by agricultural workers were cuts by sharp objects or a machine during work (67%) (Thailand National Statistical Office, 2012). In this study, there was a significant difference in the reporting of cuts from sharp objects by farm type, with rice farmers having the highest reporting rate (33%) and flower farmers the lowest (13%) (Fig. 2). In another survey of rice farmers from nine Thai villages, more than 80% reported injuries from stepping on sharp objects during plowing, and 49% reported punctures from bamboo sticks during planting (Buranatrevedh and Sweatsriskul, 2005).

Exposure prevention behaviors during the use of pesticides

In this study, most farmers reported wearing simple personal protection from dermal exposures during pesticide use such as long pants (56%), long sleeve shirts (75%), boots (68%), a cloth wrapped around their face (74%), and rubber gloves (55%) (Fig. 3). In a previous study of chili farmers, 60% reported not using gloves during mixing or spraying pesticides (Kachaiyaphum *et al.*, 2010). In Phitsanulok, agricultural workers who grew rice, vegetables, and fruit reported that only 21% wore

long-sleeved shirts or boots when spraying although 64% reported using mouth or nose covers (most likely knit balaklavas or cotton cloth wrapped around the face) (Plianbangchang *et al.*, 2009).

Most of the farmers in this study reported always using a range of good pesticide exposure prevention practices. When comparing the farming types, the flower and vegetable farming group had the highest frequency of these good exposure prevention practices (Table 5). This aligns with the observation that they also reported the highest usage of disposable paper masks, boots, and rubber and cotton gloves (Fig. 3).

These findings are encouraging because previous studies of rice farmers in Sukhothai province reported 77% had received no training in safe pesticide use (Markmee and Chapman, 2010). Similarly, 77% of chili farmers were reported to have a low level of knowledge about the use of PPE during pesticide use (Norkaew *et al.*, 2010) and in another study of chili farmers, those with a low knowledge of pesticide risks or poor pesticide protection behaviors were found to have a significantly elevated risk of abnormal serum cholinesterase levels (Kachaiyaphum *et al.*, 2010).

Surveillance data from the Thai Ministry of Public Health reported 10 177 pesticide poisoning cases in 2015 with a morbidity rate of 17.12 cases per 100 000 population (Bureau of Occupational and Environmental diseases, Center for Disease Control, Ministry of Public Health, 2015). In 2003, the government announced a national policy to control the use of pesticides and other chemicals in agriculture (Siriruttanapruk and Anantagunlathi, 2004). There are now 3796 primary care units in 74 provinces that offer an agricultural health clinic at least once per month. These clinics use a colorimetric test to screen workers that may use OP or carbamate pesticides.

Strengths and limitations of the study

The limitations of this study included a reliance on self-perception of health problems without physical health examinations, a limited number of crops that were focused on and the population was surveyed in only 3 out of 76 provinces. The strength of this study was that unlike previous work it included more than one region (three provinces) in Thailand and covered five types of agricultural workers: rice, vegetable, flower, rice/vegetable, and flower/vegetable farmers. Unlike many previous studies, the questionnaire used covered a wide range of health and safety issues, including pesticide use, MSDs and accidents, and a variety of hazardous working conditions and preventative behaviors.

Conclusion

Country-level data on injuries and illnesses and their associated costs among the 11.4 million agricultural workers in Thailand are lacking. As a result, the cost to the Thai economy of these injuries and illnesses cannot yet be estimated. Of particular concern is the lack of data on the chronic disease prevalence, occupational injuries, and MSDs among this aging population. As pesticide import volumes continue to increase, controls on pesticide sales are needed to ensure agricultural workers are trained in the safe use of these chemicals and studies of the chronic effects of pesticide use among agricultural workers and the children living in their homes are imperative. Nevertheless, the information described here can help target educational efforts by the Ministry of Public Health staff at the agricultural health clinics.

Supplementary Data

Supplementary data are available at *Annals of Work Exposures and Health* online.

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Declaration

Its contents, including any opinions and/or conclusions expressed, are solely those of the authors.

References

- Aekplakorn W. (2009) *National health examination survey, health examination survey by physical health examination the fourth year 2008–2009*. Nonthaburi: Graphico system Co Ltd. Available at <http://www.hiso.or.th/hiso/picture/reportHealth/report/report1.pdf>. Accessed May 2017.
- Basher A, Nath P, Siddique ZS *et al.* (2015) Musculoskeletal disorder (MSD) among agricultural workers. *Mymensingh Med J*; 24: 1–8.
- Berg H. (2001) Pesticide use in rice and rice–fish farms in the Mekong Delta, Vietnam. *Crop Protection*; 20: 897–905.
- Brueggeman M, Rosenthal E. (2001) *Agricultural skin diseases*. Partners in Agricultural Health Grant Coordinators Rural Wisconsin Health Cooperative. Available at <http://www.org/files/AgHealth/skin.pdf>. Accessed October 2017.
- Buranatrevedh S, Sweatsriskul P. (2005) Model development for health promotion and control of agricultural occupational health hazards and accidents in Pathumthani, Thailand. *Ind Health*; 43: 669–76.
- Bureau of Labor Statistics, United States Department of Labor. (2011) Number and rate of fatal occupational injuries, by industry section, 2011. Available at <http://www.bls.gov/iif/oshwc/cfoi/cfch0010.pdf>. Accessed May 2017.
- Bureau of Occupational and Environmental Diseases, Center for Disease Control. (2015) Manual for Occupational Health Service of Public Health officer at agricultural Health Clinic (In Thai). Available at <http://envocc.ddc.moph.go.th/uploads/media/manual/ManualClinical-new-farmers.pdf>. Accessed October 2017.
- Bureau of Occupational and Environmental Diseases, Center for Disease Control, Ministry of Public Health. (2015) Report of environmental and occupational diseases situation in 2015 (In Thai). Available at http://envocc.ddc.moph.go.th/uploads/situation/01_envocc_situation_58.pdf. Accessed October 2017.
- Bureau of Policy and Strategy, Ministry of Public Health. (2011) Thailand health profile 2008–2010. Available at http://wops.moph.go.th/ops/thp/thp/en/index.php?id=288&group_05&page=view_doc. Accessed May 2017.
- Chatzi L, Alegakis A, Tzanakis N *et al.* (2007) Association of allergic rhinitis with pesticide use among grape farmers in Crete, Greece. *Occup Environ Med*; 64: 417–21.
- Earle-Richardson G, Jenkins PL, Slingerland DT *et al.* (2003) Occupational injury and illness among migrant and seasonal farmworkers in New York State and Pennsylvania, 1997–1999: pilot study of a new surveillance method. *Am J Ind Med*; 44: 37–45.
- Hoppin JA, Umbach DM, Long S *et al.* (2014) Respiratory disease in United States farmers. *Occup Environ Med*; 71: 484–91.
- International Labour Office (ILO). (2015) Safety and health in agriculture programme on safety, health, and the environment. Available at http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_110193.pdf. Accessed May 2017.
- Kachaiyaphum P, Howteerakul N, Sujirarat D *et al.* (2010) Serum cholinesterase levels of Thai chilli-farm workers exposed to chemical pesticides: prevalence estimates and associated factors. *J Occup Health*; 52: 89–98.
- Kaewboonchoo O, Kongtip P, Woskie S. (2015) Occupational health and safety for agricultural workers in Thailand: gaps and recommendations, with a focus on pesticide use. *New Solut*; 25: 102–20.
- Kittusamy N, Mayton A, Ambrose D. (2004) *Self-reported musculoskeletal symptoms among operators of farming equipment*. Proceedings of the 2004 American Industrial Hygiene Conference, Atlanta, GA. Available at <https://www.cdc.gov/niosh/nioshtic-2/20024784.html>. Accessed December 2017.
- Kongtip P, Changfuang S, Yoosook W *et al.* (2011) Ethion exposure and biological monitoring in vegetable farmers. *J Med Assoc Thai*; 94: 286–94.

- Kongtip P, Nankongnab N, Chaikittiporn C *et al.* (2015) Informal workers in Thailand: occupational health and social security disparities. *New Solut*; 25: 189–211.
- Kongtip P, Tingsa T, Yoosook W *et al.* (2009) Health risk assessment and biomarkers of chlorpyrifos in rice farmers. *J Health Res*; 23:23–29.
- Linaker C, Smedley J. (2002) Respiratory illness in agricultural workers. *Occup Med (Lond)*; 52: 451–9.
- Markmee P, Chapman RS. (2010) Factors influencing pesticide use-related symptoms among rice farmers in Sukhothai Province. *J Health Res*; 24: 13–20.
- Ministry of Foreign Affairs, Kingdom of Thailand. (2015) Sufficiency economy philosophy: Thailand's path towards sustainable development goals. Available at http://www.mfa.go.th/SEPforSDGs/SEPThailandsPathtowardsSDGs/SEP_Thailands_Path_towards_SDGs.pdf. Accessed October 2017.
- Ministry of Labor. (2013) Notification entitled Guidance on Occupational Safety, Health and Environment for Informal Workers (in Thai). Available at http://www.shawpat.or.th/index.php?option=com_phocadownload&view=category&cid=6%3A-m—m-s&Itemid=77&limitstart=40. Accessed December 2014.
- National Institute for Occupational Safety and Health. (2001) *Simple solutions: ergonomics for farm workers*. Report No. 2001-111, 1–53. Available at <https://www.cdc.gov/niosh/docs/2001-111/pdfs/2001-111.pdf>. Accessed December 2017.
- National Statistical Office. (2015) The survey results of job characteristic in Thai people (In Thai). Available at <http://service.nso.go.th/nso/nsopublish/themes/files/lfs58/report-Feb.pdf>. Accessed May 2017.
- National Statistical Office, Ministry of Information and Communication Technology. (2012) Statistics of land, whole Kingdom: 2002–2012 (In Thai). Available at <http://service.nso.go.th/nso/web/statseries/statseries14.html>. Accessed May 2017.
- Ngowi AV, Mbise TJ, Ijani AS *et al.* (2007) Pesticides use by smallholder farmers in vegetable production in Northern Tanzania. *Crop Prot*; 26: 1617–24.
- Norkaew S, Siriwong W, Siripattanakul S *et al.* (2010) Knowledge, attitude and practice (KAP) of using personal protective equipment (PPE) for chili-growing farmers in Huarua sub-district Mueang district, Ubonrachathani Province Thailand. *J Health Res*; 24: 93–100.
- Office of Agricultural economics, Ministry of Agricultural and Cooperatives. (2015) Summary of imported pesticides [in Thai], 2015. Available at http://www.oae.go.th/ewt_news.php?nid=146&filename=index. Accessed December 2017.
- Panuwet P, Prapamontol T, Chantara S *et al.* (2008) Concentrations of urinary pesticide metabolites in small-scale farmers in Chiang Mai Province, Thailand. *Sci Total Environ*; 407: 655–68.
- Panuwet P, Siriwong W, Prapamontol T *et al.* (2012) Agricultural pesticide management in Thailand: situation and population health risk. *Environ Sci Policy*; 17: 72–81.
- Phataraphon M, Chapman RS. (2010) Factors influencing pesticide use-related symptoms among rice farmers in Sukhothai Province. *J Health Res*; 24(suppl. 1):13–20.
- Plianbangchang P, Jetiyanon K, Wittaya-Areekul S. (2009) Pesticide use patterns among small-scale farmers: a case study from Phitsanulok, Thailand. *Southeast Asian J Trop Med Public Health*; 40: 401–410.
- Prasertsung N. (2012) *Situation of pesticides used in rice fields in Suphanburi Province* (In Thai). Proceedings of the Conference on Chemical Pesticides, November 15–16, 2012. Available at http://www.thaipan.org/sites/default/files/conference2555/conference2555_0_08.pdf. Accessed December 2017.
- Pretty J, Bharucha ZP. (2015) Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects*; 6: 152–82.
- Quandt SA, Elmore RC, Arcury TA *et al.* (2001) Eye symptoms and use of eye protection among seasonal and migrant farmworkers. *South Med J*; 94: 603–7.
- Sapbamrer R, Nata S. (2014) Health symptoms related to pesticide exposure and agricultural tasks among rice farmers from Northern Thailand. *Environ Health Prev Med*; 19: 12–20.
- Schilmann A, Lacasaña M, Blanco-Muñoz J *et al.* (2010) Identifying pesticide use patterns among flower growers to assess occupational exposure to mixtures. *Occup Environ Med*; 67: 323–9.
- Siriruttanapruk S, Anantagulnathi P. (2004) Occupational health and safety situation and research priority in Thailand. *Industrial Health*; 42: 135–140.
- Skórska C, Mackiewicz B, Dutkiewicz J *et al.* (1998) Effects of exposure to grain dust in Polish farmers: work-related symptoms and immunologic response to microbial antigens associated with dust. *Ann Agric Environ Med*; 5: 147–53.
- Spiewak R. (2001) Pesticides as a cause of occupational skin diseases in farmers. *Ann Agric Environ Med*; 8: 1–5.
- Tajgman D. (2014) Extending labor law to all workers: promoting decent work in the informal economy in Cambodia, Thailand and Mongolia. Available at http://www.oit.org/wcmsp5/groups/public/—asia/—ro-bangkok/documents/publication/wcms_bk_pb_129_en.pdf. Accessed April 2017.
- Thailand National Statistical Office. (2012) Health Status of Thai Labor (In Thai). Available at <http://service.nso.go.th/nso/nsopublish/pubs/pubsfiles/LaborHealthy.pdf>. Accessed May 2017.
- Tonsri K. (2014) Labor with agricultural changing (In Thai). Available at https://www.bot.or.th/Thai/MonetaryPolicy/NorthEastern/DocLib_Research/04-Labor%20with%20Agri%20Changing.pdf. Accessed May 2017.
- Toren A, Oberg K, Lembke B. (2002) Tractor-driving hours and their relation to self-reported low-back and hip symptoms. *Applied Ergonomics*; 33: 139–146.
- World Bank. (2007) Gender issues in agricultural labor overview. Available at <http://siteresources.worldbank.org/INTGENAGRLIVSOUBOOK/Resources/Module8.pdf>. Accessed October 2017.
- World Health Organization. (2010) *The WHO recommended classification of pesticides by hazard and guidelines to classification: 2009*. Geneva: WHO Press.
- Ye M, Beach J, Martin JW *et al.* (2013) Occupational pesticide exposures and respiratory health. *Int J Environ Res Public Health*; 10: 6442–71.