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Pesticide use in Vegetable Production: A Survey of Vietnamese Farmers' Knowledge

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Abstract

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Concerns about inappropriate storage, application rates, and disposal practices of pesticides prompted this case study of Vietnamese farmers' knowledge, attitudes, and practices. 128 small-scale vegetable growers in Lam Dong Province were included in field surveys, questionnaires, and interviews. Farmers reported inappropriate mixing of pesticides and disposal methods. Many also reported ill-timed applications posing potential hazards to the human health and environment. Improved training and monitoring of pesticide residues on foodstuffs and in agricultural soils and community water supplies are needed to ensure safe farmer practices. Community-based training and education, jointly funded by local, national, and international agricultural production and food safety groups, would be a cost-effective method of minimising pesticide applications and improving food safety.

Keywords: pesticide application; pesticide disposal; vegetable pesticide residues; environmental protection; agricultural production; Vietnam agriculture

Globally, more than 45% of annual food production is lost due to pest infestation (Abhilash & Singh 2009). Pesticides have demonstrated their value by increasing agricultural productivity, reducing insect-borne and endemic diseases, and protecting plants and animals (Ecobichon 2001). However, the increased use and misuse of pesticides are of concern to agricultural workers and food consumers, and threaten the environment. Inappropriate use of pesticides can have negative effects on human health and agro-ecosystems, damage wildlife habitats, create pesticide resistance of insects and diseases, and pollute ground and surface water resources (Recena *et al.* 2006; Polidoro *et al.* 2008; Pimental & Paoletti 2009; Shormar *et al.* 2014). In tropical developing countries, the application of a wide variety of pesticides to crop plants is necessary due to high temperature and humidity; these climatic conditions lead to rapid multiplication of insects and diseases (Kannan *et al.* 1992; Abhilash & Singh 2009). In addition, the prevalence of multiple cropping systems (two or three crops each year) leads to increased pesticide use compared with agricultural practices in temperate regions. For economic reasons, in tropical agricultural systems of developing countries, many older, non-patented, inexpensive chemicals are used extensively. These compounds are often highly toxic, environmentally persistent, and capable of causing acute health problems and environmental contamination (Ecobichon 2001). The World Health Organization (WHO) reported that 20% of pesticide use in the

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world is concentrated in developing countries and that misuse poses a significant threat to the human health and environment (Hurtig *et al.* 2003).

Like other agriculture-based countries, Vietnam has a strong reliance on chemical fertilisers and pesticides in agricultural production. Pesticide use began with the start of economic liberalisation in the mid-1980s, when the private sector was allowed to import and distribute pesticides and farmers were given use rights over their agricultural land, allowing them to make independent farm management decisions. Since 1990, pesticide distribution has been in response to market demand; government regulation is involved only for registration, trade, formulation, manufacture, sale, and use permits (Nguyen 2001). From 1991 to 2005, pesticide use in Vietnam increased from 15 000 t to 76 000 t, and to about 105 000 t in 2012 with pesticide imports currently valued at US$744 million (ILS 2013). A 10-year farm-level monitoring program also showed that pesticide use increases with increasing pesticide availability, and many toxic and illegal pesticides are being used in Vietnam (Hoi *et al.* 2016). About 80% of pesticides are used incorrectly causing poor bio-efficacy and increased production costs and resulting in a greater toxic load of the environment (Nguyen 2014). According to Hoi *et al.* (2013), the active ingredients (a.i.) of pesticides in various categories – toxic category II (moderately hazardous), U (unlikely to present an acute hazard in normal use), and unknown (UK) – have increased in the Vietnamese pesticide market. In 2012 in Lam Dong Province, 1 800 t of pesticides with 90 various categories of a.i. were used to manage insects and diseases on the approximately 47 000 ha of vegetable production (Lam Dong Crop Production and Plant Protection Sub-Department, 2013).

Vegetables can play a significant role in human nutrition. They are a rich source of minerals, vitamins, and fibre. They contain a moderate amount of protein and are often low in carbohydrates. In Vietnam, principal vegetables include tomato (*Solanum lycopersicum*), chili (*Capsicum annum*), cucumber (*Cucumis sativus*), watermelon (*Citrullus lanatus*), bitter gourd (*Momordica charantia*), pea (*Pisum sativum*), French bean (*Phaseolus vulgaris*), yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*), various brassicas, and *Allium* species. Vegetable crops have been promoted to improve food security, meet local market demands, and serve the export market (Johnson *et al.* 2008). However, pesticide-free cultivation has not been attractive to farmers due to the challenges of controlling pests. According to Hoi *et al.* (2013), vegetable farmers apply pesticides intensively, and often at higher rates than permitted by the label. More than 7000 incidents of pesticide residue poisoning were reported in 2002 (Nguyen 2003). Besides acute poisoning due to direct and indirect exposure to pesticides, chronic pesticide poisoning is of concern, especially for Vietnamese farmers.

There have been numerous studies examining pesticide use on vegetables and risk exposure in developing countries in Asia (Rahman 2003; Jeyanthi & Kombairaju 2005; Atreya 2007; Xu *et al.* 2008; Weinberger & Srinivasan 2009; Zhou & Jin 2009; Srinivasan 2012). Vegetable production and marketing in Vietnam have also been studied in the last decade (Ogle *et al.* 2001; Trinh *et al.* 2003). Little is known, however, about pesticide utilisation in highland areas of northern Vietnam, although several studies have addressed the negative effects of pesticides on human health, natural food chains, and the environment (Hoi *et al.* 2009; Pham *et al*. 2011).

The purpose of this study was to investigate the knowledge, attitudes, and practices of Vietnamese vegetable growers in the Central Highland area regarding pesticide use. The study examined current management practices in vegetable production and assessed the extent of pesticide use. A survey assessed the knowledge and perceptions of local farmers regarding the safe use of pesticides to understand the farmers' views on the potential pesticide poisoning and environmental damage. This information will be useful in the development of more appropriate and sustainable pest management options and tools as well as better pesticide policies.

MATERIAL AND METHODS

Interviews and surveys were conducted in Lam Dong Province between April and December, 2013. The province is located in the Central Highland region of Vietnam, 11°12'–12°15'N latitude and 107°45'E longitude. It includes 2 cities and 10 districts and 899 311 ha of agricultural land (BTNMT-TT08 2007). Many economically important vegetable crops are cultivated in the study area including tomato (*Solanum lycopersicum*), chili (*Capsicum annum*), carrot (*Daucus carota*), chayote (*Sechium edule*), onion (*Allium cepa*), and *Brassica* species. 128 smallholder vegetable farmers were selected for interviews from

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two districts (Duc Trong and Don Duong) and city of Dalat. The sites were selected for the survey based on the importance and scale of vegetable production, agro-ecology, types of crops produced, and accessibility. Interviewers were recruited with the help of village extension workers from the professional staff of Lam Dong Plant Protection Sub-Department. Qualitative and quantitative data were collected from farmers during face-to-face, doorstep interviews and field observations. The structured questionnaire was designed based on published literature on the subject and the help of survey experts. Questions were closed-ended questions in a single-choice or multiple-choice format and some questions demanded multiple answers. Farmers were not informed beforehand to avoid bias and modifications in pesticide handling behaviour. Questions were structured to avoid leading farmers to "acceptable" answers. For example, to identify pesticide application timing, the question was phrased as 'what time of day do you apply pesticides to your crops?' to avoid promoting any particular timing of pesticide use. Similarly, reasons for mixing pesticide use were sought by asking 'why do you like to use pesticide mixtures'. The questionnaire was designed in the local language (Vietnamese) and was pretested on 15 randomly selected vegetable growers to assess question suitability. After pretesting, the questionnaire was used to obtain information on: (*i*) respondent farmers' social, professional, and farm conditions, (*ii*) pesticide use practices (i.e., types and sources of pesticide acquisition, spray equipment, time and frequency of pesticide application, pesticide spraying technique, protection measures taken during spraying, pesticide storage, etc.), and (*iii*) the perception of farmers about pesticide application [their attitudes regarding the health hazard posed by pesticides and potential environmental contamination (i.e., decision to apply pesticide, pesticide mixtures, pre-harvest interval, disposal of leftover pesticides, etc.)]. Data were analysed by descriptive statistics (frequency distribution, percentage, mean, and standard deviation) and inferential statistics (chi-squared test) using Microsoft EXCEL and IBM Statistical Package for Social Sciences (SPSS v20) software package.

RESULTS

Farmer demographics and safety training. The average size of farms in the surveyed areas was 0.43 ha. 81% of farmers interviewed were males, with 40% between 41 and 50 years of age. The safety training level differed significantly ($\chi^2 = 38.45$, $df = 8$, $P < 0.01$) among regions. 64% of vegetable growers ($n = 128$) received pesticide safety training; 29% of farmers attended integrated pest management (IPM) training, and 30% received safe and effective pesticide application training. 20% of farmers received the safe vegetable production model training while 18% attended training courses in recognizing and preventing insect and disease injury (Figure 1). 67% of respondents participated in only one training course while 27% received multiple trainings; 6% received no pesticide safety training.

Pesticide use practices. Table 1 presents the list of pesticides used by farmers in surveyed locations. No pesticides classified as extremely hazardous (Ia) or highly hazardous (Ib) were applied. 14 out of 44 were unregistered for use on vegetables. Pesticide use practices of the vegetable growers interviewed are recorded in Table 2. 82% of the farmers obtained their pesticides from authorised dealers, 16% sourced their pesticides from the open market, and 2% sourced from small, unauthorized shops. 72% mixed two pesticides and 28% mixed three pesticides together

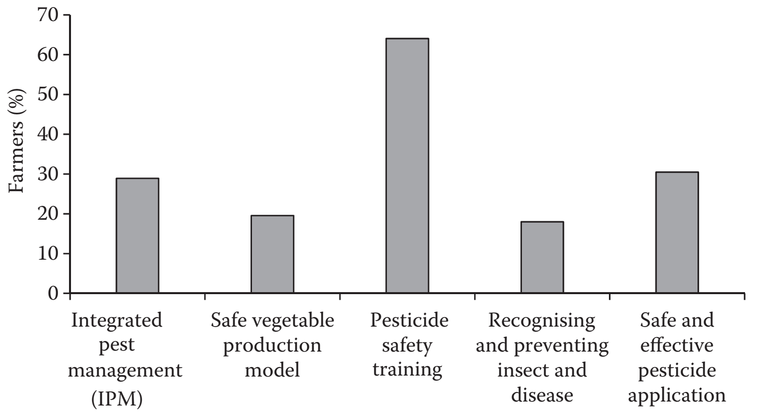

Figure 1. Percentage of farmers receiving professional training ($n = 128$)

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Table 1. List of pesticides used by farmers in studied locations, classified using the WHO Hazard Class and health effects, 2009

Pesticide	Trade name	Active ingredients	WHO class*	Registered for use on	Target pests
Insecticide 35%	Binhtox 1.8EC	Abamectin	II	tomato, cabbage	*Heliothis armigera*
	ABT 2WP	Abamectin + *B. thuringiensis*	–	cabbage	*Pieris rapae*
	Actara 25WP	Thiamethoxam	–	tomato, cabbage	*Frankliniella schultzei*
	Alphacol 700WP	Propineb	U	tomato	*Xanthomonas campestris*
	Cyper 25EC	Cypermethrin	II	rice, soybean	*P. rapae*
	Delfin WG	*Bacillus thuringiensis*	U	cabbage	*Plutella xylostella*
	Emaben 3.6WG	Emamectin benzoate	–	tomato, cabbage	*P. xylostella*
	Map Jono 700WP	Imidacloprid	II	watermelon, orange	*Phyllotreta striolata*
	Map-permethrin 50EC	Permethrin	II	soybean	*Agrotis ypsilon*
	Mapy 48EC	Chlopyrifos ethyl	III	orange	*A. ypsilon*
	Oshin 100SL	Dinotefuran	–	not registered	*P. rapae*
	Padan 95SP	Cartap	II	sugarcane, rice	*A. ypsilon*
	Pegasus 500SC	Diafenthiuron	U	tomato, cabbage	*H. armigera*
	Prevathon 5SC	Chlorantraniliprole	U	tomato, cabbage	*P. rapae*
	Radiant 60SC	Spinetoram	U	tomato	*F. schultzei*
	Secure 10EC	Chlorfenapyr	II	watermelon, citrus	*F. schultzei*
	Sumipleo 10EC	Pyridalyl	II	cabbage	*P. xylostella, P. rapae*
	Takumi 20WG	Flubendiamide	II	cabbage	*A. ypsilon, P. xylostella*
	Trigard 100SL	Cyromazine	U	cucumber, potato	*Liriomyza huidobrensis, Ophiomyia phaseoli*
Fungicide 32%	Amistar 250SC	Azoxystrobin	U	tomato	*Phytophthora infestans*
	Amistar top 325SC	Azoxystrobin + Difenoconazole	II	tomato	*Alternaria solani*
	Carbenzim 50WP	Carbendazim	U	lettuce	*X. campestris, A. solani*
	Cuzate M8 72WP	Cymoxanil + Mancozeb	–	tomato	*X. campestris*
	Daconil 500SC	Chlorothalonil	U	tomato, potato, cucumber	*Peronospora parasitica*
	Manozeb 80WP	Mancozeb	U	various crops	*P. parasitica*
	New kasuran 16.6WP	copper oxychloride + Kasugamycin	–	various crops	*Erwinia carotovona, P. parasitica*
	Kocide 53.8WP	copper hydroxide	III	potato	*E. carotovona, P. parasitica*
	Melody dou 66.75WP	Iprovalicarb + Propineb	U	tomato	*X. campestris*
	Monceren 250SC	Pencycuron	U	rice, peanut	*Rhizoctonia solani*
	Nativo 750WG	Tebuconazole + Trifloxystrobin	–	cabbage	*E. carotovona, X. campestris*
	Nebijin 0.3DP	Flusulfamide	–	cabbage	*Plasmodiophora brassicae*
	Ranman 10SC	Cyazofamid	–	tomato	*P. infestans*
	Revus opti 440SC9	Chlorothalonil + Mandipropamid	III	tomato	*A. solani, X. campestris*
	Score 250EC	Difenoconazole	III	tomato, potato	*P. infestans*
	Stepguard 100SP	Streptomycin sulfate	III	cabbage	*E. carotovona*
	Tilt super 300EC	Difenoconazole + Propiconazole	III	tea, rice	*A. solani, X. campestris, P. parasitica*

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Table 1 to be continued

Pesticide	Trade name	Active ingredients	WHO class*	Registered for use on	Target pests
Fungicide 32%	Score 250EC	Difenoconazole	III	tomato, potato	*P. infestans*
	Stepguard 100SP	Streptomycin sulfate	III	cabbage	*E. carotovona*
	Tilt super 300EC	Difenoconazole + Propiconazole	III	tea, rice	*A. solani, X. campestris, P. parasitica*
	Topsin M 70WP	Thiophanate-methyl	U	watermelon	*X. campestris*
	Vali 5SL	Validamycin	U	green-bean	*E. carotovona, R. solani*
	Viroval 50WP	Iprodione	U	rice	*X. campestris*
	Zineb Bul 80WP	Zineb	U	tomato, potato	*P. infestans, X. campestris*
Herbicide 33%	CO 2,4D 500SL	2.4D	II	rice	weeds
	Dual Gold 960EC	S-Metolachlor	III	soybean	weeds
	Glyphosan 480SL	Glyphosate	III	fruit	weeds
	Gramoxone 20SL	Paraquat	II	tomato	weeds

*II – moderately hazardous; III – slightly hazardous; U – unlikely to present acute hazard in normal use; – not listed

without considering their compatibility or active ingredients. For pesticide application, knapsack and motorised sprayers were most common (48% for each sprayer type). 67% of farmers sprayed pesticides with the wind direction to minimise inhaling pesticides and skin contact. Some farmers used raincoats or other protective clothing (22%); protective equipment used included an oro-nasal mask (17%), sunglasses (14%), gloves (16%), hat (15%), or boots (16%). Use of protective clothing and equipment during spraying did not differ among regions ($\chi^2 = 4.404$, $df = 10$, $P <$ 0.01). 41% of respondents applied pesticides more than 7 times per cropping season, 34% reported spraying pesticides 5–7 times, and 21% applied pesticides 3–4 times. Most pesticides were applied in the afternoon (52%) or early morning (46%). 48% of vegetable growers reported spraying pesticides 20 cm above the crop canopy, 41% sprayed directly on targeted insects and disease damage sites, and 11% sprayed plant tops. 97% of the farmers surveyed stored their pesticides in separate and safe places and 65% kept a diary to record necessary information and farm experiences during the cropping season.

Farmers' knowledge of pesticide application. Farmers' knowledge regarding pesticide application is provided in Table 3. 97% reported reading written information on pesticide packaging before use, including the directions on how to mix, apply, store, and dispose of pesticides. 40% of farmers reported that they initiated pest control practices when they noticed pests in their crop. 23% based their decision to apply a pesticide on calendar spray schedules, 18% on noticing crop damage, 16% on the recommendations of extension workers, and 3% due to local media reports or neighbours' recommendations. Pesticide use decisions of farmers differed significantly among the regions ($\chi^2 = 30.57$, $df = 10$, $P <$ 0.01). 88% of vegetable growers applied pesticides at low pest densities. Those farmers reasoned that the application could give higher effective prevention (54%) or reduce pest densities in subsequent crops (46%). 75% reported switching to another pesticide which had a higher toxicity if the previous one was ineffective, 14% of farmers combined and used the same pesticide with another pesticide, and 11% applied higher doses to achieve greater effectiveness. 98% of farmers applied pesticides in mixtures. 62% reasoned that mixtures would result in higher effectiveness of pests control, 34% reported a stratagem of eliminating multiple pests simultaneously, and 4% reported a potential for reduced labour cost or spraying time. 90% of farmers reported their concern about damaging natural pest enemies. 81% of those farmers claimed that pesticide use would not kill natural enemies, while 18% thought that natural enemies had been killed before pesticide use.

Attitudes concerning pesticide use and environmental damage. Table 4 provides data on farmers' attitudes regarding the potential health impacts on pesticide applicators and environmental damage. 98% of farmers were concerned about the impact of pesticide poisoning and protecting the environment. 71% reported receiving their knowledge about pesticide toxicity from pesticide labels, 18% from extension workers, and 11% from dealers. The most common methods reported for disposing of leftover

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Table 2. Pesticide use practices of vegetable growers in the Central Highland region of Vietnam

Survey question	*N*	Responses			
		frequency	% of total	mean	SD
(a) Source of agro-chemicals	135				
Authorised dealer		110	82	36.7	13.0
Small shops		3	2	1.0	1.0
Open market		22	16	7.3	3.2
(b) Number of spray applications per crop	128	0			
< 3		5	4	1.7	1.5
3–4		27	21	9.0	9.0
5–7		44	34	14.7	4.5
> 7		52	41	17.3	12.5
(c) Pesticide combination	126				
2 types		91	72	30.3	16.2
3 types		35	28	11.7	7.1
(d) Type of pesticide applicator	159				
Knapsack sprayer		77	48	25.7	21.1
Sprayer hose		6	4	2.0	1.0
Motorised sprayer		76	48	25.3	11.9
(e) Pesticide application timing	172				
Early morning		79	46	26.3	7.2
Afternoon		90	52	30.0	11.5
Noon		1	1	0.3	0.6
Other		2	1	0.7	1.2
(f) Positions of spray head	145				
20 cm above plant tops		69	48	23.0	11.8
At plant tops		16	11	5.3	1.5
Targeted insects and diseases		60	41	20.0	12.1
(g) Pesticide spraying techniques in field	153				
Spray against the wind		17	11	5.7	6.4
Spray with the wind		102	67	34.0	12.0
Walk forward		14	9	4.7	3.1
Walk backward		20	13	6.7	2.5
(h) Protective measures during spraying	538				
Raincoat or safety clothes		118	22	39.3	18.2
Oro-nasal mask		93	17	31.0	10.0
Sunglasses		73	14	24.3	11.9
Gloves		86	16	28.7	10.3
Hat		79	15	26.3	10.2
Boots		89	16	29.3	10.7
(i) Pesticide storage	130				
In a separate and safe area (outside the house)		126	96	42.0	20.1
In barn or toilet		1	1	0.3	0.6
In kitchen		1	1	0.3	0.6
No storage		2	2	0.7	1.2
(j) Farming diary	128				
Yes		83	65	27.7	25.4
No		45	35	15.0	10.1

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Table 3. Farmers' knowledge of pesticide application

Survey question	*N*	Responses			
		frequency	% of total	mean	SD
(a) Read written information on pesticide packaging before use	128				
Yes		124	97	41.3	19.6
No		4	3	1.3	0.6
(b) Decision to apply pesticide	226				
Noticing insects and diseases		92	40	30.7	18.2
Neighbours' recommendation		2	1	0.7	0.6
Calendar spray schedule		51	23	17.0	7.8
Extension workers' recommendation		37	16	12.3	2.5
Local media		4	2	1.3	1.5
Noticing crop damage		40	18	13.3	7.6
(c) Spray at low pest population density	128				
Yes		113	88	37.7	21.1
No		15	12	5.0	5.0
(d) Reasons for spraying at low pest density	125				
Higher effective prevention		67	54	22.3	8.1
Pest density reduction in the next crops		58	46	19.3	11.9
(e) When the pesticide was not effective	149				
Replace another one		111	75	37.0	15.0
Combine with other pesticides		21	14	7.0	5.0
Increase dosage		17	11	5.7	5.7
(f) Pesticide mixtures	128				
Yes		126	98	42.0	19.1
No		2	2	0.7	0.6
(g) Reasons for mixing pesticide use	140				
Higher effectiveness to control pests and diseases		87	62	29.0	5.6
Eliminate many different kinds of pests simultaneously		48	34	16.0	14.1
Others (reduce labour cost or spraying time)		5	4	1.7	2.9
(h) Concern about natural enemies in field	128				
Yes		115	90	38.3	18.3
No		13	10	4.3	3.5
(i) Effects of pesticides on natural enemies	115				
Not kill natural enemies		93	81	31.0	20.9
Natural enemies were killed before pests		21	18	7.0	3.0
Other		1	1	0.3	0.6

pesticides were emptying containers in the field (48%) or spraying until the tanks were empty (41%). Some farmers (11%) claimed to prepare an exact pesticide volume for each application. Farmers' disposal of leftover pesticides differed significantly ($\chi^2 = 41.4$, $df = 4$, $P < 0.001$) among regions. After use, most empty pesticide packages (78%) were gathered and kept in safe places, while 17% were collected and buried. There were significant differences among regions regarding the disposal of empty pesticide packages ($\chi^2 = 19.3$, df = 6, $P < 0.05$). 98% of farmers reported respecting the recommended pre-harvest interval. 78% reported getting the pre-harvest interval instructions from package labels, 15% from extension workers, and 6% from dealers.

DISCUSSION

Knowledge, attitudes, and practices concerning the pesticide use of small-scale vegetable growers (< 0.5 ha/household) in the highland area of Vietnam

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Table 4. Farmers' attitudes regarding potential pesticide poisoning and environmental damage

Survey question	*N*	Responses			
		frequency	% of total	mean	SD
(a) Concern about pesticide poisoning to user and environment	128				
Yes		125	98	41.7	17.6
No		3	2	1.0	1.7
(b) Source of pesticide toxicity information	153				
Dealer		17	11	5.7	3.5
Extension worker		28	18	9.3	5.0
Pesticide label		108	71	36.0	18.5
(c) Disposal of leftover pesticides	128				
Dump in the field		61	48	20.3	23.3
Spray until finished		53	41	17.7	10.8
Other (prepare an exact volume)		14	11	4.7	1.2
(d) Empty pesticide containers are	138				
Left in field		1	1	0.3	0.6
Collected and kept in safe places (containers, tanks ...)		108	78	36.0	19.3
Buried/burned		23	17	7.7	4.7
Other		6	4	2.0	2.6
(e) Respect the recommended pre-harvest interval	128				
Yes		125	98	42.3	19.2
No		3	2	0.3	0.6
(f) Sources of instructions for pre-harvest interval	146				
Dealer		9	6	3.0	1.7
Extension workers		22	15	7.3	4.7
On package label		114	78	38.8	16.7
Other		1	1	0.3	0.6

were surveyed. In this study, farming activities are dominated by males (81%). Similarly, Waichman *et al.* (2007) and Adjrah *et al.* (2013) reported farming was controlled by males in Brazil (97.4%) and in Togo (92%). Pesticide use in the study area appears to be influenced by authorised dealers motivated by pesticide sales. The influence of suppliers on farmers' pesticide application was previously reported for Vietnam (Hoi *et al.* 2009) and other developing countries (Epstein & Bassein 2003; Ngowi *et al.* 2007). According to our survey, a high number of farm workers received training on integrated approaches to pest management but still relied heavily on pesticides and 44 different formulations were used. Perhaps the farmers believe that using different types of pesticides is the most effective solution to control pests and diseases (Dinham 2003). Class II and III pesticides were still used widely in the studied sites. Many farmers were applying pesticides which are not registered for vegetable production thereby affecting the quality and safety of vegetables for consumption. According to one official from Lam Dong Plant Protection, the farmers have been adequately informed about the consequences of pesticide abuse but they are just ignoring the advice. They know that some pesticides are not intended for application to vegetables yet they applied because they claimed that they were very effective for controlling pests, without paying attention to the effects on their health and the environment.

Location was significantly associated with the farmers' safety training, pesticide use decisions, and the disposal of leftover pesticides and empty pesticide packages. The respondents in Don Duong district were generally more positive to pesticide use than those in Dalat and Duc Trong and there was also a very low number of farmers who had been trained on IPM concepts in Don Duong district. There was higher concern found among respondents in Dalat regarding potential health risks and environmental damage caused by the incorrect disposal of pesticide wastes. Although laws and regulations need to be consistent throughout the country, variations in

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perceptions between locations could play a significant role in their implementation. Cole *et al.* (2011) reported that knowledge about variations in perceptions between regions is of significant importance for planning purposes.

Most farmers apply chemicals at high frequency, resulting in use in excess of label specifications. Excessive application of pesticides may lead to high residue levels on plants, which may be dangerous to farmers and to vegetable consumers (Varela & Navarro 1988). Almost all (98%) farmers interviewed mix pesticides inappropriately and do not consider that this could reduce pesticide effectiveness and/or cause damage to their health or the environment. Farmers explained that mixing chemicals saves time and labour cost and that they anticipated higher pest control efficacy. However, in addition to health and environmental concerns, inappropriate mixtures of various pesticides can increase pest resistance (Metacalf 1980) and reduce a.i. effectiveness (Smit *et al.* 2002). In the studied sites, vegetable growers were often ineffectively protected, e.g. using only partially protective clothing or protective equipment. They cited economic reasons, the inconveniences involved, and lack of available protective equipment. Consequently, farmers are likely to encounter dangerously high dermal and respiratory exposure to pesticides when mixing and applying pesticides. According to Wilson and Tisdell (2001), the use of protective clothing has been insufficient in developing countries due to lack of regulations and limited education about this issue. Knapsack and motorised sprayers were used most frequently due to a lack of money for the purchase of safer equipment. William *et al.* (2006) reported that knapsack sprayers pose danger to the user because they are prone to leakage, especially as the sprayer ages. In addition, it is difficult to target only intended crops during spraying, thus, non-target crops are exposed to the pesticide.

Windy and sunny weather are the major problems faced during pesticide applications because they cause pesticide drift and volatilisation. Farmers reported not taking adequate precautionary measures for these factors. Most (67%) growers observed the wind direction, avoided spraying during high wind speed conditions, and chose the appropriate time for pesticide application, reducing their vulnerability to pesticide exposure. In contrast, a previous study (Ouluwafemi & Robert 2009) found that only 18% of farmers in Ekiti State, Nigeria observed the wind direction and some sprayed when the wind speed was high. These farmers believed that the high wind speed would help to spread the pesticide to wider areas of the field, not recognising that this practice greatly increases the potential for exposure to chemicals from both skin contact and inhalation (William *et al.* 2006).

Many farmers applied pesticides according to calendar schedules, which has been reported to reduce pests' natural enemies and ultimately increase the pest burden (Cloyd 2012). The survey also revealed that beneficial insects, birds, and other animals may have been affected in the study area since the majority (88%) of interviewees applied pesticides at low pest densities. Higher effective prevention and pest density reduction in subsequent crops were the main reasons given for spraying at low pest density. Many farmers reported that pesticide use does not kill natural enemies. There is a clear gap in education and a need for change of practice if farmers are to avoid unnecessary sprays at low pest population levels, and use pesticides only when crop damage reaches an economic threshold (Williamson *et al.* 2003).

The pesticide label is an important source of information for safe application and environmental and health risk reduction (Waichman *et al.* 2007). Almost all vegetable growers reported reading the pesticide label. If followed, these directions would help farmers avoid pesticide under- or over-application, understand the pesticide toxicity potential, and adhere to pre-harvest interval restrictions. Almvik *et al.* (2012) reported that current regulations in Vietnam set the pre-harvest interval to 7 days for most pesticides, whereas in Norway, the interval is 14 days. 98% of farmers claimed to be aware of the pre-harvest interval but reported that they do not always observe it. Harvest time is mostly determined by vegetable dealers and market demand (N. Le, personal communication, Dec 2013). Thus, vegetables may be harvested immediately after a pesticide application. Similarly, Nguyen *et al.* (1999) reported that vegetable growers do not usually respect the recommended pre-harvest interval. According to Jeyanthi and Kombairaju (2005), when pesticides are applied immediately before harvest, the level of pesticide residues on produce was greatly increased.

Many farmers interviewed kept a diary during the cropping season. Keeping a written diary is a key component of managing an efficient farm operation and would help vegetable growers keep track of activities, production, and important events, and likely improve

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decision making. Most (96%) interviewed farmers reported storing pesticides in separate and safe places outside the house while some (2%) bought only the quantity needed for immediate use. This indicated that the farmers were aware of possible health effects of improper pesticide storage. According to Tijani (2006), storing pesticides in places other than in facilities designated for this purpose poses risks to users and non-users, especially children. Many surveyed vegetable growers reported that they collected and stored empty pesticide containers in safe and protected places outside the house before transfer to designated points where they were gathered and treated by pesticide companies. However, they were using improper leftover pesticide disposal methods. The most common method for disposing of leftover pesticide was pouring it out in the field or spraying until the tank was empty. These inappropriate methods pose potential hazards for non-target flora and fauna as well as increasing the likelihood of elevating pesticide residue levels on vegetable products.

The absence of adequate pesticide applicator training, and subsequent assessment, increases the danger of pesticide use, including health impacts on applicators, increased pest residues on food, damage to non-target plants and animals, and environmental contamination. Excessive pesticide use also increases the cost of vegetable production. Thus, researchers and extension personnel need to work with farmers to improve their knowledge about appropriate pesticide use methods and to develop IPM strategies that will significantly reduce their reliance on pesticides.

CONCLUSIONS

This study provides information on the knowledge, attitudes, and practices of small-scale vegetable farmers in the Central Highlands of Vietnam regarding pesticide use. Survey responses indicate the widespread improper use of pesticides including excessive application frequency, inappropriate pesticides mixtures, dangerous leftover pesticide disposal methods, and inadequate pre-harvest intervals that pose hazards to the human health and environment. Although farmers reported that they read pesticide labels, they also report frequently not following label instructions including applying pesticides with insufficient protective clothing and equipment. Many farmers reported receiving professional training about pesticide use but also reported not following instructions in day-to-day activities. The majority of farmers interviewed use pesticides according to their own opinions and experience and ignore potential threats to personal health and environmental contamination. Farmers appear to be unaware or uncaring about the extent of pesticide residue levels on local food products or long-term health effects of pesticide residues on consumers. A comprehensive pesticide training program is needed involving close interaction among researchers, extension workers, agribusiness, and farmers to improve farmers' knowledge of the appropriate use, storage, and disposal of agro-chemicals and to reduce farmers' heavy reliance on pesticides in pest control by implementing IPM strategies.

Recommendations

Mandatory training and knowledge/understanding assessment. Current training events reach the majority of farmers, but there is no assessment of the knowledge gained or level of understanding of the impact of their actions. Training should be mandatory, yearly, and include assessment of knowledge and understanding gained as well as intent to adopt improved practices.

Monitoring farmer practices. Without monitoring of farmer practices, training is simply an expensive, time-consuming exercise. Regional or national policy about pesticide use should be implemented. Policy discussions should be a part of training sessions. To improve farmer practice, unannounced farm visits should be implemented during which farmers are required to provide documentation of pesticide application, storage, and disposal facilities and procedures, equipment and protective clothing. Fines and/or mandated additional training sessions could be levied against policy and practice violators.

Monitoring pesticide residues on agricultural products and soil and water resources. Food safety and environmental protection are the intended consequences of farmer training and practice monitoring. Without monitoring food product pesticide residue levels and water quality, the impact of training will be unknown. A baseline of food residues and soil and water pesticide levels is the first step in implementing a monitoring program.

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