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Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia

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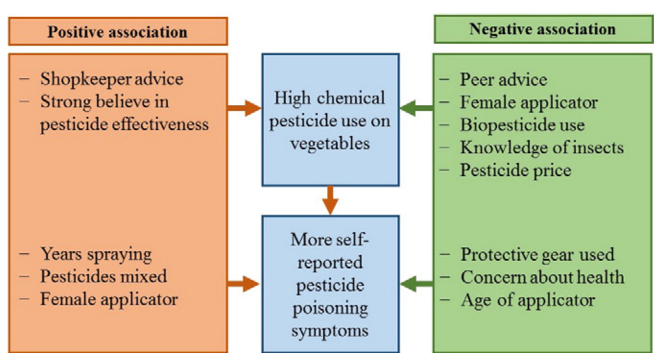
HIGHLIGHTS

- Vegetable farmers' pest management was studied in Cambodia, Laos, and Vietnam.
- Farmers were aware of health risks from pesticides, but considered pesticides indispensable.
- Low knowledge of beneficial and harmful insects was associated with more pesticide use.
- Farmers who sought advice from pesticide shopkeepers tended to use more pesticides.

GRAPHICAL ABSTRACT



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ABSTRACT

This study aimed to understand farmers' knowledge, attitudes, and practices regarding agricultural pest management and synthetic pesticide use in Southeast Asia. Data were used from 900 farm households producing leaf mustard (*Brassica juncea* (L.) Czern. et Coss.) and yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) in Cambodia, Laos and Vietnam. Farmers heavily depended on synthetic pesticides as their main method of pest control. Most farmers were aware of the adverse health effects associated with pesticide use and covered body parts while spraying, but also considered pesticides to be highly effective and indispensable farm inputs. Farmers were largely unable to distinguish between common beneficial and harmful arthropods. Greater knowledge about this was associated with less pesticide use while greater awareness of pesticide health risks was associated with fewer observed poisoning symptoms. For the average farm and while controlling for other factors, farmers who sought advice from friends and neighbors used 45% less pesticide, but those who sought advice from pesticide shopkeepers used 251% more pesticide. Pesticide use was 42% less when a woman was in charge of pest management and 31% less when farmers had adopted biopesticides. These findings suggest relevant entry points for interventions aimed at reducing pesticide dependence.

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1. Introduction

Agricultural pesticide use is rapidly increasing in many developing countries, but particularly in Southeast Asia (Kunstadter, 2007; Schreinemachers and Tipraqsa, 2012). Annual growth in pesticide imports is estimated to be 61% for Cambodia, 55% for Laos, and 10% for Vietnam (Schreinemachers et al., 2015). The fast rate of this increase poses enormous challenges to manage the associated risks to people and ecosystems. For instance, Skretteberg et al. (2015) studied fruit and vegetables imports from Southeast Asia into four European countries and found pesticide residues above maximum residue limits in 33% of samples from Vietnam and 9% from Thailand. It is generally well understood that pesticides pose the greatest risk to applicators and their families, particularly in developing countries where a large segment of the population is involved in agriculture, spraying is done manually with simple equipment, and applicators are not fully aware of the risks of exposure (Jensen et al., 2011; Mengistie et al., 2017; Praneetvatakul et al., 2013).

In Southeast Asia, such farm-level risks are relatively well documented for Thailand and Vietnam (e.g. Grovermann et al., 2013; Hoai et al., 2011; Hoi et al., 2009; Houbraken et al., 2016; Lamers et al., 2011; Panuwet et al., 2012; Poramacom, 2001; Praneetvatakul et al., 2013; Riwthong et al., 2015; Schreinemachers et al., 2011). However, there is a lack of similar knowledge for lower income countries such as Cambodia and Laos (exceptions being Jensen et al., 2011 for Cambodia and Brown and Khamphoukeo, 2010 for Laos). There, widespread pesticide use is a much more recent phenomenon and regulatory frameworks and monitoring systems are even weaker than those of their higher income neighbors (McCann, 2005; Schreinemachers et al., 2015).

The development of policies and regulations addressing the issue requires information about current pest management practices and associated risks at the farm level. The objective of this study was to improve our understanding of farmers' knowledge, attitudes and practices regarding pest management in Southeast Asia. Our study focused on vegetables because pesticide use is particularly high for these crops, which are susceptible to a large number of arthropod pests and diseases while consumers prefer unblemished pest-free vegetables.

2. Data and methods

2.1. Conceptual framework

This study applied the concepts of knowledge, attitudes and practices (KAP). A KAP assessment tells us what people know about the problem, how they feel about it, and how they currently behave. This framework assumes that a change in practices is the cumulative result of a change in knowledge and attitudes. The separation between knowledge, attitudes and practices has been frequently employed in studies on pesticide exposure (e.g. Brown and Khamphoukeo, 2010; Karunamoorthi et al., 2012; Pasiani et al., 2012; Recena et al., 2006; Yang et al., 2014). The information obtained from such studies is useful to target policy interventions to close knowledge gaps or to correct prevailing misconceptions.

Knowledge here refers to farmers' understanding of pests, pesticides and good agricultural practices. Three exercises, available from the authors on request, were used to test farmers' knowledge. The first exercise showed 12 color photos of common arthropods, including six harmful arthropods (e.g. flea beetle, diamondback moth, and pod borer for vegetable legumes) and six beneficial arthropods (e.g. spider, ladybird beetle, and lacewing). Respondents had to indicate which arthropods they thought damaged crops. In the second exercise, respondents were asked to match five photos of adult insects to five photos of their larvae/nymphs. In the third exercise, respondents were presented with six pesticide safety pictograms commonly found on the label of pesticide containers in all three countries, and were asked to explain the meaning of each. For each test, the proportion of correct answers was calculated. The use of pesticide safety pictograms to test farmers' knowledge has been done in previous studies (e.g. Mengistie et al., 2017; Pedlowski et al., 2012), but testing farmers' knowledge about the role and lifecycle of arthropods has, to our knowledge, not been done before.

Attitudes here refer to farmers' beliefs about pesticide effectiveness and health effects, including possible misconceptions. It was measured using 16 statements listed in Appendix Table A1. The initial statements were taken from LePrevost et al. (2011) but major adjustments were made to make them more relevant to the local context and understandable to farmers. To keep it simple, farmers could answer “agree” or “disagree.” Eight statements measured farmers' beliefs about pesticide health risks (e.g. "Pesticides can enter the body through the skin") and six statements recorded farmers' belief about the necessity and effectiveness of pesticides (e.g. “Using pesticides increases farm profits” and “Commercial vegetable production without pesticides is impossible”). Each set of statements was made into an index.

Self-perceived pesticide poisoning symptoms were also recorded. We listed 14 possible symptoms (e.g. headache, vomiting, dizziness, abdominal pain, skin rashes, and blurred vision) and asked each respondent whether they did or did not experience the symptom after spraying pesticides. This test is commonly applied in pesticide risk studies (e.g. Dasgupta et al., 2005; Jensen et al., 2011). The total number of symptoms was expressed as a score. Farmers' perceptions might be quite different and less accurate than that of trained experts, but nevertheless provide important information because farmers decide on a course of action based on their own perceptions of reality.

Practices here refer to farmers' actual behavior (decisions, actions) that demonstrate knowledge of and attitudes toward pest management and pesticides. Five alternative measurements were used that all referred to the respondent's most recently harvested vegetable parcel. First, the quantity and the purchase value of pesticides used was recorded by asking for the names of all pesticide products used, the number of times the product was applied, the average quantity per application, and the amount of money spent. Second, the number of times the farmer sprayed was recorded. Third, we recorded the use of protective gear (e.g. boots, mask, gloves, and hat). Fourth, we asked if different pesticides were mixed in a single spray and if yes, how many. Fifth, the average number of hours or days between spraying and re-entering the field (also known as the re-entry interval) and between last spraying and harvesting (also known as the pre-harvest interval) was recorded.

2.2. Data

Our study collected farm-level data from Laos, Cambodia and Vietnam. These countries represent a scale of average levels of pesticide use intensity from low average levels in Laos to high levels in Vietnam (Schreinemachers et al., 2015). The study's scope was narrowed to leaf mustard (*Brassica juncea* (L.) Czern. et Coss.) and yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) as two vegetable species commonly cultivated in the three countries. Leaf mustard, also known as green mustard or mustard greens, is cultivated year-round, but cultivation peaks in the cooler period from October to March. In Laos and Vietnam yard-long bean cultivation is mostly carried out during the hot season starting from April, but in Cambodia it is mostly grown in the cooler season from November to March.

The study started with focus group discussions in two selected villages per country to get a better understanding of the issues and to inform the subsequent questionnaire development. The questionnaire had 14 pages and is available with the online version of this article. The questionnaire was designed in English, translated into Lao, Khmer and Vietnamese, and tested with farmers before the start of the data collection. Minor adjustments were made to tailor the questions to each country.

We took a representative sample of farmers from the main production areas and main production season per country using a stratified random sampling strategy. There are unfortunately no lists of bean and mustard farmers from which to draw a random sample. Therefore, in each country two provinces were selected with the largest planted area for these crops according to national statistics or the assessment of local scientists (Table 1). In consultation with local extension officers, the main production districts were selected and a list was made of villages in these districts where the crop was grown. This list was randomized and visited in descending order. For each village a list was constructed of all farmers who had cultivated the crop in the most recent season. Ten farmers were randomly selected from this list per village, though sometimes there were fewer farmers available. Additional villages were visited until there were 150 completed questionnaires per crop. The total sample size was 900 households. There was no overlap between the samples of bean and mustard farmers.

Interviews took about 90 min on average. At the start of the interview, enumerators explained the purpose and contents of the questionnaire and ensured confidentiality of the data provided. All respondents were explicitly asked for their verbal consent to participate. Answers were recorded on paper questionnaires and entered in a customized MS Excel workbook after the interviews. The anonymized data are available from the authors upon request.

General questions about crop management were asked to the main person responsible for the crop, and specific questions about pest management were asked to the main person responsible for this, while questions about spraying practices and perceived pesticide poisoning symptoms were asked to the person doing the spraying. Mostly this was the same person, but occasionally farm tasks were divided and different persons completed different parts of the questionnaire.

2.3. Analytical approach

Data were analyzed using descriptive statistics, showing means and standard deviations. For some variables, the relative standard errors were large and medians are shown instead. We did not compare differences between leaf mustard and yard-long bean but focused on the comparison between countries in showing the data.

A regression model was employed to identify determinants of pesticide use and perceived pesticide poisoning symptoms. Previous studies that have applied regression analysis to identify determinants of pesticide use include Chen et al. (2013) and Rahman (2015) while Dasgupta et al. (2005) is an example of study using regression analysis to find determinants of pesticide poisoning symptoms. Following these previous studies, pesticide use was quantified in kilograms of formulated product divided by the plot area in hectares. It was further divided by the length of the growing season to get the quantity per hectare per week. This measure is preferred over the frequency of pesticide spraying because farmers tend to mix different pesticides in single sprays. Severe outliers, identified as values higher than the upper quartile plus 3 times the interquartile range, were dropped from the regression analysis. The logarithm of pesticide use was used to reduce the effect of positive outliers. Zeros were replaced by half the minimum non-zero quantity before taking logarithms to prevent these observations from being dropped in the analysis.

Hypotheses were tested that a greater understanding of pests, pesticides and good agricultural practices and more awareness about health effects is associated with lower levels of pesticide use. Other determinants hypothesized to be associated with less pesticide use per hectare were: larger plot size, more years of experience in cultivating the particular crop, previous training in pest management, higher price of pesticides, and the use of alternative methods to control pests and diseases. Farmers seeking advice from pesticide shopkeepers were assumed to use more pesticides as previous studies have suggested that shopkeepers stimulate their customers to use more pesticides (Hoi et al., 2013; Schreinemachers et al., 2015).

Determinants of pesticide poisoning were analyzed using a simple count of the number of different pesticide poisoning symptoms reported by the pesticide applicator. We did not weight the different symptoms. The hypotheses were tested that greater quantities of pesticides are associated with more poisoning symptoms and that greater knowledge about pests and awareness about adverse health effects were associated with fewer poisoning symptoms. Other determinants assumed to increase poisoning symptoms include the number of pesticide products mixed together and years of using pesticides. Determinants assumed to reduce pesticide risk include the number of protective gear used by the applicator and sex of the applicator. Model parameters were estimated using ordinary least squares. Data for the two crops and three countries were combined to increase variation and improve the precision of the estimates. Dummy variables were added to control for systematic differences between countries and crops.

Table 1
Sample size characteristics of the households in the study.

	Laos	Cambodia	Vietnam
Provinces	2	2	2
Districts	7	6	8
Subdistricts/communes	3	12	13
Villages	30	22	41
Households	300	300	300
Period of the data collection	Jul–Aug 2015	Aug–Sep 2015	Jul–Oct 2015
Enumerators employed	8	7	7

3. Results

Vegetable production in Laos, Cambodia and Vietnam is small-scale (Table 2). The average farm size was 0.41 ha. The average farm household had 4.7 persons and the person in charge of pest management was 47 years of age. About 38% of farm managers in Laos and Cambodia were female, while in Vietnam this was 50%. These percentages are typical for vegetable farming in peri-urban areas of Southeast Asia, where agriculture is labor intensive but men are often employed outside agriculture, leaving their spouses in charge of farm operations.

Areas planted to leaf mustard and yard-long bean were small in Laos and Cambodia and extremely small (450 m^2 on average) in Vietnam (Table 3). The average length of growing period was 7–8 weeks for leaf mustard, though farmers often re-sowed their field after harvest or used staggered sowing to extend the harvest period. Yard-long bean has a longer growing period of 3–4 months. The frequency of fertilizer use shows that the intensity of production is much higher in Vietnam and Cambodia than in Laos. Median marketable crop yields and profit margins were also higher in Cambodia and Vietnam than in Laos. However, median total profits were more similar because farmers in Laos planted a larger area.

Table 2
Characteristics of the farm and the person in charge of crop production, average per household, 2015.

	Laos (n = 300)	Cambodia (n = 300)	Vietnam (n = 300)	Total (n = 900)
Farm characteristics				
– Household size (persons)	4.88 (1.60)	4.91 (1.72)	4.23 (1.42)	4.67 (1.61)
– Farm size (ha)	0.46 (0.47)	0.47 (0.63)	0.31 (0.29)	0.41 (0.49)
Characteristics of the person in charge of production				
– Age (years)	44.57 (9.09)	45.11 (12.10)	50.13 (9.58)	46.61 (10.63)
– Female (proportion)	0.37	0.29	0.50	0.38
– Able to read and write (proportion)	0.95	0.85	1.00	0.93
– Completed secondary school or higher (proportion)	0.32	0.27	0.27	0.29

Note: Standard deviations in brackets.

Table 3
Crop cultivation practices of leaf mustard and yard-long bean in Laos, Cambodia and Vietnam, average per farm, 2015.

	Leaf mustard			Yard-long bean		
	LAO	KHM	VNM	LAO	KHM	VNM
Planted area (ha)	0.21 (0.15)	0.12 (0.15)	0.04 (0.03)	0.31 (0.21)	0.14 (0.14)	0.05 (0.02)
Length of growing period (weeks)	6.6 (1.9)	8.7 (1.1)	7.7 (1.9)	18.2 (4.0)	12.7 (2.9)	15.5 (2.4)
Fertilizer applications (times/growing cycle)	0.9 (0.5)	2.7 (1.4)	3.1 (1.4)	1.9 (1.3)	3.6 (3.4)	5.0 (3.5)
Marketable yield (t/ha)[a]	5.6	15.0	12.4	3.0	12.5	21.8
Farmgate selling price (USD/kg)[a]	0.50	0.35	0.34	0.62	0.37	0.33
Gross margin (1000 USD/ha)[a]	0.36	1.51	2.47	0.49	2.09	5.08

Notes: Standard deviations in brackets.
[a] Medians LAO = Laos; VNM = Vietnam; KHM = Cambodia.

Respondents were shown 15 photos of the most common pest problems in yard-long bean and leaf mustard, and were asked to select which of these problems they had encountered in their most recent crop. Farmers selected 11 photos on average, which is indicative of the vast challenge of managing multiple pests and diseases. The three most often selected photos were pod borer, armyworm and blue butterfly for yard-long bean and diamondback moth, flea beetle, and cabbage butterfly for leaf mustard. These choices show the relative importance of insect pests. Farmers thought that pests and diseases reduced their crop yield by 18% on average.

To solve problems with pests and diseases, 98% of the farmers in Vietnam and 76% of the farmers in Cambodia sought advice from a local pesticide shop (Fig. 1). In Laos this was only 20% and friends, neighbors and lead farmers were more important sources of information. In Vietnam, the government extension service was relatively important; 40% of the farmers received advice from it and there usually was an extension officer in every commune. However, only about 10% of the farmers in Laos and Cambodia received advice from extension officers.

3.1. Knowledge and attitudes

Shown photos of 12 common arthropods, respondents found it difficult to tell which were beneficial and which were harmful (Appendix Table A2). Most respondents (74%) could correctly tell that butterflies/moths and caterpillars damage their crops. They were much better at identifying harmful arthropods (69% correct on average) than at identifying beneficial arthropods (23% correct on average). For instance, 40% of the respondents knew that honey bees are beneficial and 38% knew that spiders are beneficial, but only 5% knew that lacewings are beneficial and only 1% knew that grubs of ladybird beetles are beneficial. These low percentages showed a critical lack of knowledge about beneficial arthropods and an inclination to regard all arthropods as pests.

It was an even greater challenge for the respondents to associate insect adults with their larvae. For instance, only 10% of the respondents could match a photo of an adult ladybird beetle with a photo of its characteristic black-yellow colored grub. The average share of correct answers was only 10%—worse than if respondents had matched the photos at random, which would give 20% correct answers on average. The low percentage suggests a complete lack of understanding about the lifecycle of insects.

Respondents performed much better in the exercise to interpret pesticide safety symbols. Here, respondents in Cambodia were correct for 59% of the symbols, and even 69% and 98% in Vietnam and Laos, respectively.

Most applicators reported having experienced a range of pesticide poisoning symptoms after spraying (Fig. 2). Commonly observed symptoms were headache (40%), fatigue (36%), dizziness (33%) and excessive sweating and salivation (28%). Applicators in Cambodia had a much higher frequency of perceived poisoning symptoms, and many had experienced relatively serious symptoms such as vomiting (20%), muscle twitching (25%), and chest discomfort (25%). Twelve applicators in Laos (4%) said they fell unconscious after spraying.

Pesticide risk beliefs were measured using nine statements on the relationship between pesticides and health (shown in Appendix Table A1 and summarized in Table 4). Applicators were aware of health risks because for 75% of the statements the respondents perceived an association between pesticide use and adverse health effects. For instance, 82% of the applicators in Cambodia said that when spraying pesticides they were worried about getting cancer. However, this exercise also revealed certain misconceptions. For instance, 32% of the applicators in Laos thought that drinking alcohol after spraying helped to eliminate side effects and 42% of the applicators in Cambodia thought that herbicides were not dangerous to humans.

Seven statements were used to collect applicators' opinions on the effectiveness of pesticides (Appendix Table A1 and summarized in Table 4). Applicators held a strong belief that pesticides are effective and a necessary farm input. For instance, 79% agreed with the statement that mixing pesticides makes them more effective (a practice that increases health risks to applicators and consumers, besides inducing resistance in insects more rapidly) and 66% agreed with the statement that good pesticides are those that kill all insects immediately. About 84% of the applicators in Laos and Cambodia thought that biopesticides

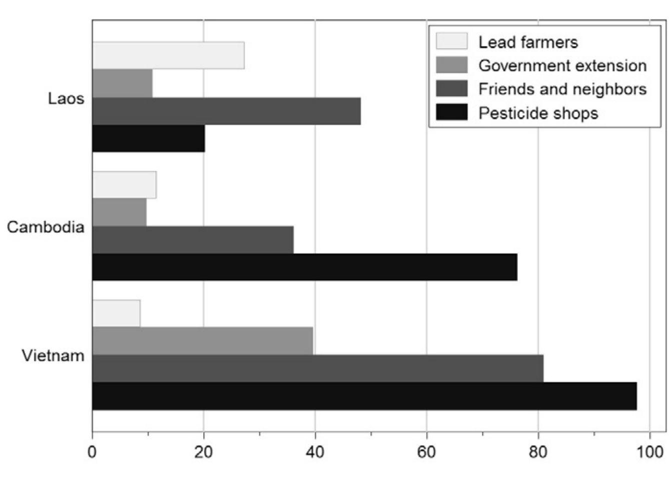

Fig. 1. Sources of advice on pest management in Laos, Cambodia and Vietnam, in % of vegetable farmers, 2015.

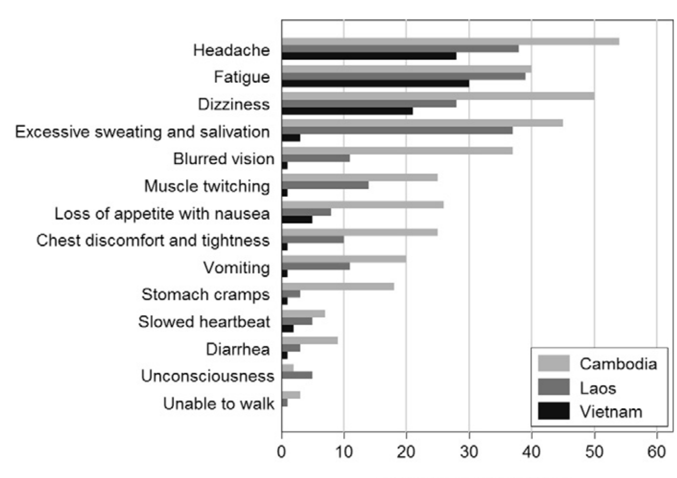

Fig. 2. Perceived health effects and pesticide risk beliefs of vegetable farmers in Laos, Cambodia and Vietnam, 2015.

Table 4
Pest management knowledge and risk beliefs of vegetable farmers in Laos, Cambodia and Vietnam, 2015.

	Laos (n = 300)	Cambodia (n = 300)	Vietnam (n = 300)	Average (n = 900)
Pest management knowledge (in proportion of correct answers)				
— Able to distinguish arthropods pests from beneficial arthropods	0.44	0.39	0.55	0.46
— Harmful arthropods	0.62	0.67	0.79	0.70
— Beneficial arthropods	0.26	0.12	0.31	0.23
— Able to associate adult insects with their larvae/grubs	0.10	0.02	0.10	0.07
— Able to correctly interpret pesticide safety symbols	0.98	0.59	0.69	0.75
Pesticide risk beliefs (score)				
— Level of understanding of health risks[a]	0.57	0.64	0.55	0.59
— Belief that pesticides are effective and necessary[b]	0.75	0.82	0.74	0.77

[a] Higher score indicates more awareness about health risks.
[b] Higher score indicates stronger belief that pesticides are effective and necessary.

were not as effective as synthetic pesticides, but this was only 43% in Vietnam, where biopesticides are more widely available and used.

3.2. Pest management practices

Synthetic pesticides were used by all vegetable farmers sampled in Vietnam and 96% in Cambodia, but 18% of Lao farmers indicated they did not use them (Table 5). Kilograms of formulated product used per hectare per week as well as pesticide expenditures were much higher in Vietnam than in Cambodia and Laos. Surprisingly, farmers in Laos sprayed more frequently than in the other countries, likely because farmers in Cambodia and Vietnam have higher opportunity costs for their labor time and try to be more efficient by using higher concentrations and mixing more pesticides together in single sprays. Cambodian applicators mixed an average of 3.7 pesticides together in a single spray.

The share of farmers that handpicked insects in their fields also indicates relative labor scarcity. In Laos, 82% of the respondents did this, but this was only 60% in Cambodia and 17% in Vietnam, despite the fact that plot sizes are much smaller in Vietnam and handpicking is therefore more doable. The use of other alternative methods to control pests was rare in all countries, except for biopesticide use in Vietnam (78%) and rotation with non-host crops in Cambodia (47%). No farmers used yellow and blue sticky traps to monitor and control virus-spreading insect vectors such as aphids, whitefly and thrips; pheromone traps to control pod borers; or the intentional promotion of natural enemies. This could mainly be because alternative technologies such as biopesticides, colored sticky traps or pheromone lures are not widely available in these countries.

The data also show that women were much involved in pesticide spraying with 49% of the applicators in Vietnam and 24% in Cambodia

Table 5
Farmers' pest management practices in leaf mustard and yard-long bean in Laos, Cambodia and Vietnam, average per farm, 2015.

	Laos (n = 300)	Cambodia (n = 300)	Vietnam (n = 300)	Average (n = 900)
Pesticide use				
— Spraying frequency (sprays/week)	1.21	0.77	0.52	0.83
— Using synthetic pesticides (proportion)	0.83	0.94	1.00	0.92
— Using biopesticides (proportion)	0.00	0.01	0.74	0.25
— Quantity of synthetic pesticides (kg/ha/week)[a]	0.68	0.80	1.08	0.90
	(1.87)	(1.19)	(1.27)	(1.41)
— Quantity of biopesticides (kg/ha/week)[a]	0.00	0.09	0.23	0.13
	(0.00)	(0.72)	(0.37)	(0.50)
Spraying practices[b]				
— Applicator is female (proportion)	0.24	0.24	0.49	0.33
— *Re*-enter interval (days)	1.10	0.83	1.48	1.14
— Pre-harvest interval	7.08	5.12	5.15	5.70
— Mixing different pesticides (proportion)	0.63	0.71	0.88	0.75
Other control methods used (proportion)				
— Pick and destroy insects by hand	0.81	0.61	0.17	0.50
— Rotate with non-host crop	0.02	0.43	0.10	0.18
— Grow crop under insect nets[c]	0.00	0.21	0.22	0.15
— Trap or barrier crop	0.04	0.09	0.00	0.04
— Blue/yellow sticky traps	0.01	0.00	0.04	0.02
— Pheromone traps	0.00	0.00	0.01	0.01
— Release/promote natural enemies	0.00	0.01	0.00	0.01
Use of protective gear (proportion)[b]				
— Long-sleeved shirt	0.99	0.93	0.99	0.97
— Long trousers	0.99	0.92	0.99	0.97
— Mouth cap	0.51	0.85	0.96	0.79
— Hat	0.69	0.59	0.93	0.74
— Rubber boots	0.97	0.41	0.86	0.74
— Gloves	0.94	0.41	0.66	0.66
— Raincoat or coverall	0.23	0.23	0.18	0.21
— Eye cover	0.35	0.11	0.18	0.20
— Respirator	0.01	0.00	0.00	0.00

Notes: Standard deviations in brackets.
[a] Severe outliers and missing values omitted.
[b] Of farmers spraying.
[c] Of farmers producing leaf mustard.

and Laos being female. These percentages were somewhat surprising because during the focus group discussions, participants said that pesticide spraying is a men's job because the backpack sprayers are heavy—an indication that the prevailing gender norms expect men to do the spraying, which in reality is often done by women as men are employed elsewhere.

Finally, regarding protective gear used during spraying, the use of respirators, common in Western countries, was very rare. Most applicators covered their arms, legs and the top of their head. This behavior confirmed the risk beliefs exercise, in which 92% of the respondents agreed with the statement that pesticides enter the body through the skin (Appendix Table A1). However, mouth, eyes and hands were less commonly covered, which may either imply that applicators are less aware of other routes of entry or that they find it inconvenient to cover these body parts.

3.3. Regression results

The number of observations available for the regression analysis was much below the 900 farmers interviewed for this study. Enumerators and respondents had difficulties to accurately quantify pesticide use in Cambodia and especially in Laos. In 79 cases it was not possible to quantify pesticide use and in 141 cases the quantity was unrealistic as based on the criterion for identifying severe outliers specified in Section 2.3. This reduced the sample in Laos by 50% and in Cambodia by 23%. The results must therefore be interpreted with caution as there is a potential for selection bias as less successful farmers are perhaps more likely to have been dropped from the sample.

The model for pesticide use levels was overall significant ($p < 0.01$) and explained 30% of the variation in the quantity of pesticide use (Table 6). Parameter signs were as hypothesized except previous training in pest management or good agricultural practices, which was positive but not significant ($p \geq 0.10$). The results showed that a 1% increase in plot area was associated with a 0.23% reduction in pesticide use per hectare per week for the average farm and while controlling for all other factors. Pesticide use on the average farm was 42% less if a woman was in charge of pest management than if a man was in charge of it. Similarly, for the average farm and while controlling for all other factors, pesticide use was 251% higher when the farmer sought advice from pesticide shopkeepers, but 45% lower when the farmer sought advice from friends or neighbors, while advice from extension officers had no significant effect on pesticide use.

Greater knowledge of beneficial and harmful arthropods was associated with lower levels of pesticide use. Greater awareness about adverse health effects was not significantly associated with lower levels of pesticide use, but farmers who held a stronger belief that pesticides are effective and indispensable tended to use more pesticides. The pesticide purchase price was negatively associated with use and appeared elastic with a 1% increase in pesticide price associated with a 1.1% lower pesticide use. The use of biopesticides and the handpicking of insects were associated with lower levels of pesticide use. The adoption of biopesticides by the average farmer and while controlling for all other variables was associated with 31% lower pesticide use. However, the effect of insect nets and rotation with non-host crops was not significant.

A large proportion of the observations in Laos was dropped from the analysis because of missing or unrealistic values for pesticide quantities. The regression analysis was therefore also done excluding all observations from Laos. The signs of all covariates remained the same except for training and leaf mustard which switched signs but were insignificant in both regressions. Covariates that were significant in the regression including Laos were also significant in the regression excluding Laos, except knowledge of arthropods, which became insignificant.

Table 7 shows the determinants of the number of pesticide poisoning symptoms perceived by applicators. The model's overall goodness of fit was 29%. Two coefficient signs were contrary to what was expected. First, female applicators reported 3.2 symptoms more than male applicators, controlling for all other factors including pesticide quantity, which may be because female applicators were more attentive to symptoms rather than experiencing more health effects. Second, for the average farm and while controlling for all other factors, greater knowledge of beneficial and harmful insects was associated with more symptoms.

Other coefficient signs were as expected. Larger quantities of pesticide use, more years of using pesticides, and the mixing of different pesticides were, ceteris paribus, associated with a greater number of reported poisoning symptoms. The use of protective gear and awareness of adverse health effects was associated with fewer symptoms. Finally, farmers in Cambodia and Laos reported more symptoms than those in Vietnam.

The results of this second regression model were also tested for the effect of excluding Laos from the analysis. The signs of all covariates

Table 6
Determinants of pesticide use by leaf mustard and yard-long bean farmers in Laos, Cambodia and Vietnam, 2015.

Determinants (units)	Coefficient	SE	Elasticity[a]	Sign.
Experience in crop (years)	−0.016	0.007	−0.23	**
Plot size (ln hectare)	−0.233	0.092	−0.23	**
Woman in charge of pest management (0/1)	−0.534	0.145	−42.01	***
Received training in pest management (0/1)	0.230	0.164	0.13	
Sought advice from neighbors and friends (0/1)	−0.593	0.159	−45.41	***
Sought advice from extension officer (0/1)	−0.082	0.181	−9.34	
Sought advice from pesticide shopkeeper (0/1)	1.282	0.227	251.37	***
Belief that pesticides are effective (index)	0.010	0.004	0.67	**
Concern about adverse health effects (index)	−0.008	0.006	−0.62	
Knowledge about arthropods (index)	−0.010	0.004	−0.48	**
Laos (binary)	0.004	0.367	−6.16	
Cambodia (binary)	−0.890	0.291	−60.63	***
Leaf mustard (binary)	−0.115	0.145	−11.82	
Pesticide price (USD/kg)	−0.023	0.003	−1.08	***
Used biopesticides (0/1)	−0.355	0.176	−30.94	**
Rotated with non-host crops (0/1)	0.270	0.193	28.60	
Used insect nets (0/1)	0.141	0.204	12.78	
Picked and destroyed insects by hand (0/1)	−0.309	0.180	−27.78	*
Observations (n)	589			
F-value	15.15			***
Adjusted R^2	0.30			

Notes: Sign. = Significance levels ***$p < 0.01$, **$p < 0.05$, * $p < 0.10$. Dependent variable is pesticide use in natural logarithm of kg/ha/week.

[a] For continuous variables this is the elasticity at the mean and can be interpreted as the % change in pesticide use resulting from a 1% change in the independent variable. For dummy (0/1) variables this is the % change in pesticide use resulting from a switch of the dummy from 0 to 1 at the mean of all other variables and was calculated following Kennedy (1981) as 100[exp(coefficient $*$ − 1/2 $*$ SE) − 1].

Table 7
Determinants of the number of pesticide poisoning symptoms experienced by leaf mustard and yard-long bean farmers in Laos, Cambodia and Vietnam, 2015.

Determinants (units)	Coefficient	Standard error	Significance
Quantity sprayed (kg/ha/week, ln)	1.256	0.450	***
Number of pesticides mixed	1.154	0.480	**
Years of using pesticides	0.190	0.070	***
Woman applicator	3.227	1.400	**
Age of the applicator	−0.136	0.070	**
Number of protective gears used	−1.154	0.490	**
Concern about adverse health effects (index)	−0.142	0.040	***
Knowledge about arthropods (index)	0.200	0.040	***
Leaf mustard	−0.045	1.320	
Laos	10.408	2.160	***
Cambodia	20.041	2.030	***
Constant term	4.707	7.160	
Observations (n)	614		
F-value	23.80		***
Adjusted R^2	0.29		

Notes: Significance levels ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

remained the same and covariates that were significant in the regression including Laos were also significant in the regression excluding Laos, except for pesticide mixing, which became insignificant ($p > 0.10$).

4. Discussion

4.1. Pesticide dependence

This study showed that vegetable farmers in Laos, Cambodia and Vietnam heavily depend on pesticides for managing pests and diseases in leaf mustard and yard-long bean. Farmers were generally satisfied with the effectiveness of these products and felt that they were necessary, although farmers were aware of adverse health effects. Farmers more or less knew how to protect themselves and knew the meaning of pesticide safety symbols on pesticide containers.

These general findings confirm those of several previous studies (e.g. Pasiani et al., 2012; Pedlowski et al., 2012). Ríos-González et al. (2013) described how smallholder banana farmers in Mexico self-justify the use of pesticides as the perceived benefits outweigh the perceived costs to environment and human health. It is notable that we found no significant relationship between farmers' concerns about their health and the quantity of pesticides they used, but we did find higher quantities among farmers that were especially satisfied with the effectiveness of pesticides.

It appears that raising awareness about pesticide health risks is not enough to reduce actual use, although higher awareness is associated with fewer self-reported poisoning symptoms as it may induce people to protect themselves better. This effect has also been observed in other studies (Jensen et al., 2011; Keifer, 2000). The lack of association between perceived health risks and pesticide use may be explained by the fact that farmers believe that health risk can be controlled through protection and correct handling, although very few actually implement this in full (Ríos-González et al., 2013).

4.2. Entry points for intervention

This study's findings identify several novel entry points to reduce pesticide dependence. First, pesticide dependence can be reduced by increasing farmers' capacity to distinguish harmful from beneficial arthropods as well as to understand lifecycle of arthropods. Farmers in our sample had very little knowledge of these and tended to consider every arthropod a pest. Previous studies showed that farmers often have very limited knowledge about the pests and diseases they are dealing with (Adam et al., 2015; Midega et al., 2012), but did not show if more such knowledge is associated with less pesticide use.

Second, interventions that promote the local sharing of knowledge can help to reduce pesticide use. Farmers seeking advice from pesticide shopkeepers were observed to use much more pesticides than farmers seeking advice from friends and neighbors. This finding builds on several previous studies that show the importance of local knowledge sharing in pest management, including farmer field schools (e.g. Ríos-González et al., 2013; Van den Berg and Jiggins, 2007). A notable finding was the minimal contribution of government extension systems to reduced pesticide use. Traditionally, extension is assumed to be the main channel for transferring knowledge and technologies to farmers. An early study for rice farmers in Laos, found a high influence of technicians on farmers' insect pest management decisions (Heong et al., 2002), which appears to contradict our finding for vegetables. Reducing pesticide dependence will require a concerted effort from both the public and private sector, with support from local and international non-governmental organizations.

Third, efforts to reduce pesticide dependence need to aim at both men and women. To our knowledge, this study is the first to show the important role of women in vegetable pest management in Southeast Asia. They are in charge of pest management on 38% of the farms in Laos and Cambodia, and 49% of the farms in Vietnam. The quantity of applied pesticides was much lower when women were in charge of pest management. An earlier study for Nepal found significant differences in pest management knowledge and decisions between men and women, but did not analyze its relationship to pesticide quantities (Atreya, 2007). Our study's finding is important because agricultural training or IPM training often targets male household members as they are assumed to be the ones in charge of pest management. We agree with Atreya (2007) that IPM training needs to be gender-sensitive as this aspect is often overlooked.

Finally, ease of regulation and active promotion of biopesticides and other IPM component technologies can drastically reduce chemical pesticide use. The adoption of biopesticides is common in Vietnam but not in Cambodia and Laos. Government regulations in Southeast Asia and elsewhere often do not differentiate between biopesticides and synthetic pesticides, although biopesticides have a much lower health and environmental risk.

4.3. Study limitations

An important drawback in the applied regression models is that we did not control for environmental parameters and pest and disease pressure, which are likely to influence pesticide use as farmers with more pest problems are likely to spray more. However, the causality of this relationship may also run in the opposite direction as increased spraying may lead to increased pest pressure by promoting pesticide resistance of pests and eliminating beneficial organisms (Regev, 1984). Previous studies have also suggested that much of the pesticide use is used in a preventive rather than curative way (Grovermann et al., 2013).

The use of pesticide quantity as the dependent variable is problematic because of high measurement error in farmers' recall of pesticide amounts. There is also a lot of variation in different pesticide products in terms of the concentration of active compounds and risk to human health and the environment. Such variations together with measurement error and the omission of variables measuring pest pressure are likely to account for a large share of the unexplained variance in the regressions.

We did not fully exploit the full extent of our data and further analyses are possible. Previous studies have applied canonical correspondence analysis to test correlations in the data, for instance, to analyze how farm household characteristics relate to knowledge and perceptions (e.g. Houbraken et al., 2016; Yang et al., 2014). Other studies have used structural equation analyses to test the validity of the assumed pathway from knowledge to attitudes to household decision (e.g. Bayard and Jolly, 2007; Frick et al., 2004). On request, the authors will provide the data and questionnaires for further analysis.

5. Conclusion

Vegetable farmers in Laos, Cambodia and Vietnam heavily depend on chemical pesticides for managing pests and diseases in leaf mustard and yard-long bean. Greater use of pesticide use is associated with a greater number of self-perceived pesticide poisoning symptoms. Pesticide dependence can be reduced by increasing farmers' knowledge about beneficial and harmful arthropods, by stimulating local knowledge sharing while regulating the role private pesticide retailers, and by promoting the use of alternative methods of pest control such as biopesticides. Interventions to reduce pesticide dependence must be gender-sensitive and recognize that female farmers play an important role in pest management and tend to use smaller quantities of pesticides than men.

Declaration of interest

The author report no potential conflict of interest.

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Appendix A. Supplementary data

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