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Abstract

Vegetable legumes are important crops in tropical agriculture, but they are susceptible to a substantial number of arthropod pests and plant diseases. Using farm-level survey data for 240 farm households growing yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*) in Thailand and Vietnam, this study shows that farmers' main problem is the legume pod borer (*Maruca vitrata*). Farmers heavily rely on the use of synthetic pesticides to manage this pest and no other control methods are generally used. Small cultivated areas under yard-long bean (particularly in Vietnam), a high level of satisfaction with pesticides, and a lack of market demand for pesticide-free produce are formidable challenges for the introduction of integrated pest management (IPM). It is important that IPM methods, if they are to be adopted by farmers, do not reduce profits and that farmers can experiment with these methods while awareness is raised about the risk of pesticide exposure in the general population.

Keywords: Agriculture, *Maruca vitrata*, IPM, pesticide misuse, crop protection policy

Introduction

Vegetable legumes are important crops in Southeast Asia. Crops such as yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*), cowpea (*Vigna unguiculata*) and green beans (*Phaseolus vulgaris*) account for a significant share of the total area under vegetables and are important sources of plant proteins and micronutrients in the human diet. Capable of fixing atmospheric nitrogen, these leguminous crops also play an important role in managing soil fertility. Legumes, in particular vegetable legumes, are highly susceptible to a wide range of arthropod pests and diseases. Among the documented pests, legume pod borer (*Maruca vitrata*) is considered one of the most serious pests in tropical Asia and sub-Saharan Africa (Sharma, 1998). Yield losses of up to 80% have been reported in various vegetable and grain legumes due to pod borer damage (Singh *et al.*, 1990; Afun *et al.*, 1991; Dreyer *et al.*, 1994; Ulrichs and Mewis, 2004).

At present, farmers in Southeast Asia, as elsewhere, rely almost exclusively on the application of synthetic pesticides to manage pod borer and other arthropod pests and diseases. Previous studies found that Cambodian farmers sprayed up to 20 times per season with five different pesticides mixed together per tank and sprayed on major vegetables including yard-long bean (Sodavy *et al.*, 2000). Bean growers in Bangladesh reportedly sprayed weekly or twice weekly to control pod borers (Hoque *et al.*, 2002). Pod borer moths and larvae are nocturnal and the larvae feed on floral buds, flowers, and pods. As the larvae are exposed on leaves only for a short time after hatching, there is only a brief window for effective insecticide use and much of the sprayed insecticide does therefore not reach its target. We observe that farmers tend to respond by increasing their spraying frequency or resorting to more toxic products.

The intensive and rapidly increasing use of pesticides is creating serious problems as it exposes farm workers, consumers and ecological systems to the risk of pesticide residue accumulation. In developing countries such risks are difficult to manage due to a lack of public and policy awareness (Schreinemachers and Tipraqsa, 2012). Chronic problems related to the overuse and misuse of agricultural pesticides have been reported for many parts of South and Southeast Asia and China (*e.g.* Mazlan and Mumford, 2005; Schreinemachers *et al.*, 2011; Xu *et al.*, 2008).

In Vietnam, rapid growth in pesticide use started with economic liberalization in the mid-1980s when the private sector was allowed to import and distribute pesticides and when farmers were given rights of use over their agricultural land, allowing them to make independent farm management decisions (Lamers *et al.*, 2013). From 1991 to 2007, the volume of agricultural pesticides as formulated products (*i.e.*, active ingredients as well as inert ingredients such as solvents, emulsifiers and adjuvants) increased from 20,000 to 77,000 tons, which is an average annual growth of 8.5% over a 16 year period (*ibid.*). As a result, there have been very significant problems with the contamination of vegetables and in ecosystems with pesticide residues, particularly in the Red River Delta (Hoai *et al.*, 2011; Nishina *et al.*, 2010; Van Hoi *et al.*, 2009) and also in mountainous areas (Lamers *et al.*, 2011).

The contamination of food with pesticide residues is also a serious problem in Thailand (*e.g.* Athisook *et al.*, 2007; Posri *et al.*, 2006). From 1987 to 2010, Thailand experienced a six-fold increase in the quantity of formulated pesticide products applied per hectare of agricultural land (Praneetvatakul *et al.*, 2013). The government had been promoting the use of pesticides for decades to stimulate agricultural productivity and only since the late 1990s has tried to promote more sustainable methods of pest management (*ibid.*). However, public investment in integrated pest management (IPM) is very limited (Schreinemachers *et al.*, 2012).

Previous studies have shown that the legume pod borer can be managed using sex pheromones to capture male moths (Downham *et al.*, 2004) and biopesticides such as various commercial formulations of *Bacillus thuringiensis* (Bt) (Srinivasan, 2008, 2012). The legume pod borer also has a wide range of natural enemies and can be managed through biological control (Waterhouse and Norris, 1987; Sharma, 1998; Ulrichs *et al.*, 2001; Huang *et al.*, 2003; Arodokoun *et al.*, 2006), but this is incompatible with current spraying practices that rely on broad-spectrum synthetic insecticides. The legume pod borer is prone to developing resistance against such insecticides, as reported for several countries in Southeast Asia (Ulrichs *et al.*, 2001) and sub-Saharan Africa (Okeyo-Owuor *et al.*, 1983; Atachi and Sourokou, 1989; Ekesi, 1999).

This study was carried as part of a research and development project aimed at improving the livelihoods and income generation capacity of small-scale vegetable legume farmers in Southeast Asia (Thailand and Vietnam) and sub-Saharan Africa (Benin and Kenya) by developing a simple, economical, and environmentally sound IPM strategy for legume pod borer control. The project seeks to accomplish this through refining existing IPM technologies based on sex pheromones, entomopathogens, and botanicals, and combining these with species-specific natural enemies of the pod borer for introduction and release throughout Southeast Asia and sub-Saharan Africa.

Against this backdrop, the objective of the present study is to describe how farmers in Thailand and Vietnam presently manage their pest problems in vegetable legumes in order to identify suitable entry points for the introduction of IPM. The study uses the case of yard-long bean, which is one of the most important vegetable legumes in Southeast Asia. Yard-long bean is consumed as a green vegetable and eaten raw or cooked in a variety of dishes.

The paper is structured as follows. We first explain the site selection and data collection methods applied for this study. The results first describe the general characteristics of yard-long bean production systems in Thailand and Vietnam before focusing on pest problems and their management. The discussion relates these findings to the potential and challenges for rolling out an IPM program for legume pod borer control.

Materials and methods

Farm-level data were collected in the main yard-long bean production areas in Thailand and Vietnam, as identified by local experts. In Thailand, data were collected in the central region, which is suitable for the growth of various vegetable crops with a hot and humid climate and good access to water for irrigation and to markets for selling the produce. Apart from yard-long bean, commonly cultivated vegetables in this region are kangkong (*Ipomoea aquatica*), Chinese chive (*Allium tuberosum*), Chinese kale (*Brassica oleracea* var. *alboglabra*), and pak choi (*Brassica rapa* var. *chinensis*). Within the central region, the provinces of Ratchaburi, Pathum Thani, and Kanchanaburi were selected for carrying out the survey as these provinces have relatively large areas under yard-long bean. In 2009, yard-long bean was planted on nearly 3,786 hectares in these three provinces with Pathum Thani accounting for 60% of this area (DOAE, 2010).

In Vietnam, the study was conducted in the northern districts of Gia Lam, Dong Anh and Hoai Duc, which are the three most important districts for yard-long bean production in the Hanoi area. Farms are generally small. In Dong Anh the average area of agricultural land per farm worker is only 0.051 ha. Farmers produce various types of vegetables as well as rice. Based on information from local experts (district agricultural offices in Thailand and local scientists from the Vietnam Academy of Agricultural Sciences) villages were selected where yard-long bean was grown.

Data were collected using a combination of qualitative and quantitative survey methods. The qualitative part used the tools and techniques of Participatory Rural Appraisal (PRA), including focus group interviews and problem ranking. This was used to develop a general understanding of the situation in yard-long bean cultivation, including the technologies used, monthly price changes, area trends, and marketing constraints.

This was followed by face-to-face interviews with yard-long bean growers to get more quantitative data on yard-long bean cultivation, pest and disease problems and other production constraints. In each selected village, all yard-long bean growers were selected for an interview. In Thailand, 20 villages were included and 120 farmers were interviewed. In Vietnam, the survey included seven villages and 120 farm managers were interviewed. The personal interviews used a structured questionnaire and were carried out from November 2010 to January 2011 in Thailand and from January to April 2011 in Vietnam.

The questionnaire recorded general information about farms, arthropod pest problems and plant diseases in yard-long bean production, pest management methods, pesticide handling practices, and costs and returns in yard-long bean production. Arthropod pests and diseases problems were recorded by asking farm managers to first list their five major pest and five major disease problems. They were then asked to rank these, separately for pests and diseases. From these data we calculated the percentage of farm managers who had listed a particular pest or disease problem and the average rank given. The most important pest and plant disease was given a rank of five, the least important a rank of one. Pests and diseases not mentioned by a respondent were given a rank of zero for calculating the average.

Results

Production systems

In both survey locations, the focus group discussions revealed that farming has gradually shifted from the cultivation of paddy rice to vegetables and other high-value crops over the last three decades. In Vietnam, many farmers in the study sites still grow rice in the dry and wet seasons with 85% of the rice used for home consumption. Farmers grow a variety of different vegetables, the main types being cabbage, yard-long bean, mustard green, cauliflower and Chinese cabbage. Though most of the produce is sold, 38% of the households also consumed some of their own yard-long bean.

Table 1 Average household characteristics of yard-long bean producers in Thailand and Vietnam, 2010

Farm household characteristic	Thailand		Vietnam	
	Mean	SD	Mean	SD

General farm characteristics				
Age of respondent (years)	46.5	9.4	46.4	9.1
Family size (people/household)	4.3	1.8	4.6	1.0
Experience in farming (years)	19.4	12.3	28.3	9.2
Experience in yard-long bean (years)	15.4	11.8	12.6	6.4
Farm size, owned (ha)	1.54	1.98	0.19	0.10
Yard-long bean production				
Planted area (ha)	1.25	0.92	0.08	0.05
Yield (tons/ha)	5.90	2.93	23.23	2.23
Farm gate selling price (USD/kg)	0.57	0.32	0.37	0.06
Cropping cycles per year	2.43	0.79	1.43	0.50
% of produce sold	99.4	-	99.6	-
Main planting period (first crop)	April/May		February	
Main planting period (second crop)	October		June	
Irrigation	Ditch and dyke system with boats and pumps, furrows, sprinkler		Pump from channel and spray with hose, furrows	

In Thailand, the average household planted yard-long bean 2.4 times per year on a total area of 1.25 ha; in comparison, the average farm size was 1.54 ha (Table 1). Other cultivated crops included cucumber, chili, rice, sugarcane, mustard green, asparagus, cauliflower, sponge gourd, and others. Yard-long bean producers in Vietnam planted an average of 1.43 cycles of beans per year on a total area of only 0.08 ha, which compares to an average farm size of 0.19 ha. This shows that in both countries, yard-long bean is produced by small-scale operations.

The average pod yield was 5.9 t/ha per cropping cycle in Thailand and 23.2 t/ha in Vietnam. The average yield in Thailand was relatively low, but comparable to the national average yield of 6.15 t/ha as reported by Benchasri and Bairaman (2010). The large difference in average pod yield can be explained by differences in production systems and especially the intensity of cultivation, as described in the following.

There are two distinct systems of yard-long bean production in Thailand. In Kanchanaburi province, it is cultivated as an upland crop requiring sprinkler or furrow irrigation while in

Pathum Thani province most farmers use the *rong nam* cropping system. This is a kind of dike-and-ditch system in which crops are grown on raised beds surrounded by channels with boats used to navigate through the field, irrigate the crop and transport the harvest. Creating and maintaining the beds is labor intensive, but the system helps to protect crops from seasonal floods and eases some farm operations. Yard-long bean production in Vietnam is very intensive. Farmers plant their yard-long bean at a high density using virtually every square meter of the plot and tend their plants individually. As in Kanchanaburi, farmers in Vietnam use furrows to water their plants, but sometimes also use a hose to water individual plants.

The three main commercial cultivars in Vietnam are ‘Xanh dai,’ ‘Hat trang’ and ‘Hat tim’. Many more cultivars were available in Thailand; the survey recorded 17 different ones, yet just two of these, ‘Sorn Dang’ and ‘Lamnanche’ were used by 58% of the growers. Thai farmers like to try different cultivars as 65% had switched cultivars in the last three cropping seasons. The main reason for switching cultivars were better characteristics of the bean pods, such as a bigger size, greater firmness, better shape, taste, or color.

The average farm gate selling price converted to US dollar was 0.37 USD/kg in Vietnam and 0.57 USD/kg in Thailand. However, average prices varied much within the year. In Vietnam, prices were low in April and May when the market supply was high and gradually increased towards the end of the year; in Thailand, there was no such trend in 2010.

Arthropod pests and plant diseases

Table 2 lists the major arthropod pests on yard-long bean as reported and ranked by the farmers during the survey. Pod borer was reported by 88% and 100% of the respondents in Thailand and Vietnam, respectively, and given the highest rank in both countries. In Thailand, aphids were the second most important arthropod pest problem, mentioned by 63% of the respondents. In Vietnam, armyworm (*Spodoptera litura* and *S. exigua*), bean butterfly

(*Lampides boeticus*), and bollworm (*Helicoverpa armigera*) were all considered as major pest problems and were mentioned by nearly all growers.

Table 2 Arthropod pest problems in yard-long bean cultivation, in Thailand and Vietnam, 2010

Pest problem (Scientific name)	Thailand		Vietnam	
	% farmers	Rank	% farmers	Rank
Pod borer (*Maruca vitrata*)	88	4.1	100	5.0
Armyworm (*Spodoptera litura*)	29	1.1	99	3.5
Bean butterfly (*Lampides boeticus*)	13	0.5	100	2.9
Aphids (*Aphis craccivora; A. glycines*)	63	2.2	3	<0.1
Bean spider mite (*Tetranychus spp*.)	22	0.7	40	1.2
American bollworm (*Helicoverpa armigera*)	12	0.5	97	1.4
Thrips (*Megalurothrips usitatus*)	28	1.0	41	0.5
Bean flies (*Ophiomyia phaseoli; Melanagromyza sojae*)	1	<0.1	17	0.5
Onion armyworm (*Spodoptera exigua*)	3	0.1	2	<0.1
Stink bug (*Nezara viridula*)	5	0.2	0	0.0
Broad mite (*Polyphagotarsonemus latus*)	3	0.1	2	<0.1

Note: % farmers who mentioned the pest among their five most important arthropod pest problems. Rank (0-5) quantifies the importance of the problem, a higher rank means more important. Rows are sorted in descending order of the average rank of both countries.

This finding confirms that of Loan (2012) who identified the pod borer as a major pest during flowering to pod forming stage in Vietnam and Poramarcom (2010) who identified pod borer as a major pest on yard-long bean in Thailand and identified aphids as the most important pest of yard-long bean in Thailand. Aphid adults and nymphs not only cause direct feeding damage, but can also transmit aphid-borne mosaic virus resulting in severe yield losses (Benchasri *et al.*, 2011). Although the information on secondary pests of yard-long bean is scarce in Vietnam, armyworms, bollworm, bean fly (*Ophiomyia phaseoli*) and aphid (*Aphis craccivora*) were reported to be the key pests besides *M. vitrata* in Thailand (Poramarcom, 2010).

Of the farmers surveyed in Thailand, 36% reported small or zero yield losses due to pod borer, 32% reported yield losses in the range of 10-25%, and 29% reported yield losses in the range of 26-50%, and 4% reported yield losses above 50%. In field trials conducted in Kamphaeng Saen, Thailand during March - May 2012, it was found that the borers could lead to at least 28% pod damage if the crop was left unprotected. Hence, the perceived yield losses by most of the respondents in Thailand matched with the results from our field trials.

Farmers in Vietnam felt that the available insecticides provided an effective means of control and 95% of the respondents perceived that harvest losses due to pod borer were below 10%. However, it was found from the field trials at Gia Lam district in Hanoi, Vietnam that the borers could lead to 30% pod damage resulting in only 0.45 t/ha of marketable pods, if the crop was left unprotected, during April - May 2012. Hence, it is possible that the pod borers could cause about one-third of marketable yield losses in yard-long bean, if the crop is left unprotected.

In terms of plant diseases, leaf rust caused by *Uromyces vignae* was identified as extremely problematic with virtually all farmers reporting the problem in both countries (Table 3). *Yellow mosaic virus*, leaf spot caused by *Mycosphaerella cruenta* and root rot caused by *Fusarium solani* and *Rhizoctonia solani* were other major problems in Vietnam, while Thai bean growers had more problems with damping off (a fungal disease affecting seedlings) caused by *Pythium* spp. Although plant diseases are prevalent, a large share of the farmers in Thailand (48%) did not report significant crop yield losses from them. For all plant diseases combined, the average crop yield reduction as perceived by the Thai farmers was roughly 15%.

Table 3 Plant disease problems in yard-long bean cultivation in Thailand and Vietnam, 2010

Disease problem	Thailand		Vietnam	
	% farmers	Rank	% farmers	Rank
Leaf rust	98	4.4	99	4.5
Leaf spot	29	1.1	84	2.5
Root rot	23	0.8	98	2.4

Damping off	65	2.8	10	0.2
Yellow mosaic virus	1	<0.1	91	2.7
Powdery mildew	6	0.2	58	1.8
Root-knot nematode	3	0.1	1	<0.1

Note: % farmers who mentioned the pest among their five most important arthropod pest problems. Rank (0-5) quantifies the importance of the problem, a higher rank means more important. Rows are sorted in descending order of the average rank of both countries.

Pest management

The use of synthetic pesticides is the main method of pest management used by 92% of Thai yard-long bean growers and 100% of their Vietnamese counterparts, confirming several previous studies showing their reliance on chemical pesticides as a primary mode of pest control in Thailand (e.g. Plianbangchang *et al.*, 2009) and Vietnam (e.g. Van Hoi *et al.*, 2009). Nine farmers (8%) in Pathum Thani province in Thailand produced pesticide-free yard-long bean for a niche market, which shows that it is economically and technically possible to produce yard-long bean without pesticides as long as there is a market for this.

Non-synthetic methods of pest management included mostly biopesticides and were used by 55% of the Thai farmers and reportedly by 100% of the Vietnamese farmers. However, further inspection and consultation with local experts in Vietnam showed that none of these were actually biopesticides. According to local experts, pesticide traders sometimes give incorrect information to the farmers, telling them that the pesticides purchased are not harmful to their health because they are biopesticides. Very few farmers tried to control pests by removing infected plants from their field or through intercropping. In Thailand, only one farmer had heard of trap crops and one farmer had heard of the use of pheromones to manage arthropod pests.

The average Thai yard-long bean growers used 16.3 kg of formulated pesticide products per hectare per cropping cycle. Abamectin, cypermethrin, methomyl, carbosulfan and EPN were the most common pesticides used by Thai yard-long bean growers (Table 4). The latter three are highly hazardous chemicals and leave residues if the pre-harvest interval (the period of time between the last pesticide application and the safe harvesting of the crop) is not observed. Hence, it is not uncommon to have exceedingly high levels of pesticide residues in the green bean. For example, an earlier report had confirmed the presence of several toxic pesticides including methomyl, triazophos, chlorpyrifos, methamidophos, omethoate, dicofol and dimethoate to a maximum of 15-fold higher than the maximum residue limits (MRLs) in yard-long bean from Thailand (PAN UK, 2006). In Vietnam, abamectin, fipronil, cypermethrin, lambda-cyhalothrin, and cartap were the pesticides mostly commonly applied. The latter three pesticides belong to the synthetic pyrethroids and carbamate groups. It has already been reported that more than 75% of the pesticide products used in Vietnam against arthropod pests are organophosphates, pyrethroids and carbamates (Thang 1999; Johansen *et al.*, 2003). Thus the current survey also confirmed the high prevalence of carbamates and synthetic pyrethroids. Since yard-long bean is grown in smaller plots, growers usually buy smaller packs of pesticides. An earlier study has documented the discrepancy in the label information for large packages (intended for official inspection) and for small packages (intended for farmers) (Van Hoi *et al.*, 2009) leading to pesticide misuse. For instance, the pre-harvest interval for abamectin was 7 days according to the information on the large packages, but the label on the small packages mentioned only 3 days, which makes this product more attractive for farmers. Similarly, the pre-harvest interval for permethrin recommended on the large package was 12 days, while on the small package only 7 days was mentioned. Other pesticides such as fipronil did not even have any pre-harvest interval information on the small packages, though on the large packages 14 days (for rice and beans) was indicated. Hence, it is apparent that pesticide use on yard-long bean in Vietnam may not be safe, since the yard-long bean harvest is done at least twice in a week, which may not leave sufficient time to get the pesticide residues to levels below the MRL. In addition, the pesticide use is currently higher on vegetables compared to other crops in Vietnam. For instance, the pesticide use per hectare in the Red River delta is 5.52 kg per cropping season for vegetables compared with 3.34 kg/ha for rice and 0.88 kg/ha for other food crops (Van Hoi *et al.*, 2009).

Virtually all farmers in both countries felt that pesticides provided an effective means of pest and disease control and were satisfied with their effectiveness to control the legume pod borer. According to the farmers, the use of pesticides made their crops look healthier, more marketable, and helped them to get a better price for their produce. Asked if their intensity of pesticide use has changed in the past five years, 23% of the Thai farmers thought it had increased and 6% thought it had decreased. Perceived reasons for the increase included a greater extent of pest damage and more difficulties in managing pests. These observations might point to the development of resistance against commonly used pesticides. Although resistance of legume pod borer to commonly used pesticides has not yet been documented for Thailand or Vietnam, resistance has been reported in other Southeast Asian countries (Ulrichs *et al.*, 2001). Hence, it becomes imperative to assess the resistance of legume pod borer to commonly used pesticides in Thailand and Vietnam.

Of the Thai respondents, 41% indicated a willingness to try alternative methods of pest management if these were provided to them, but 59% responded that they were not interested as they thought these methods would not be effective. Some farmers mentioned that alternatives can only be useful if all farmers adopt, as they were concerned that pests would otherwise concentrate in their fields.

Table 4 Aspects of pesticide use in yard-long bean in Thailand and Vietnam, in % of farmers using pesticides, 2010

Aspect of pesticide use	Thailand	Vietnam
Spraying frequency		
Two times per week	23	1
Weekly	64	80
Less frequent or depending on pest infestation	13	19
Satisfaction with insecticides to control pod borer		

Very satisfied	2	97
Satisfied	96	3
Not satisfied	2	0
Mix different pesticides in one spray	90	100
Five main pesticides used	Abamectin, cypermethrin, methomyl, EPN, carbosulfan	Abamectin, fipronil, cypermethrin, lambda-cyhalothrin, cartap

Spraying practices

Weekly pesticide spraying was the most common practice used by 64% of the Thai yard-long bean growers who used pesticides; another 23% sprayed twice a week (Table 4). Of those growers using pesticides, 87% indicated they did preventive (prophylactic) spraying, while 37% indicated an increased spraying frequency if they detect an increase in pest problems in their field (*i.e.*, curative spraying). This is in line with earlier findings that also reported pesticide application as a prophylactic measure in Thailand (Plianbangchang *et al.*, 2009). In Vietnam, 80% of the respondents indicated spraying once a week while only one farmer sprayed twice a week. An earlier survey among the vegetable farmers in the same study sites in Vietnam also showed that about 50% of the respondents sprayed less than 11 times with 8-10 days intervals in one season (3-4 months) on average (Johansen *et al.*, 2003).

In Thailand, spraying was typically done using a power sprayer, used by 54% of the respondents, or a mechanized pump sprayer, used by about 40% of the respondents. Manual pump sprayers are no longer commonly used. Yet in Vietnam, most farmers used either a portable manual pump sprayer or a mechanized pump sprayer (backpack type), which was also confirmed by Toan (2013).

All yard-long bean growers in Vietnam and 90% of the growers in Thailand mixed two or three pesticides together. Van Toan (2011) previously reported the use of pesticide ‘cocktails’ (mixture of 3-5 pesticides) in Vietnam. The use of such mixtures is a common practice to manage pests on vegetables in South and Southeast Asia; for instance, Kabir *et al.* (1996)

reported that country bean (*Lablab purpureus*) growers in Jessore, Bangladesh sprayed such a mixture daily or every alternate day to manage *M. vitrata*. Respondents on our survey felt this made the spraying more effective and it also saved time and labor in spraying. The mixing of different pesticide compounds is not recommended because the compounds might interact to modify the toxicity of the chemicals to humans (Crop Protection Association, 2007). Changes in absorption, translocation or metabolism of mixed pesticides can also reduce the effectiveness of the mix in controlling pests and damage the crop.

In Thailand, most of the spraying was done by the farm manager. Respondents explained that they would like to hire labor for doing the spraying, but it was difficult to find people willing to work on the farm. Nearly all farmers said they used some types of protective gear such as plastic boots (83%) hats/caps (77%), and face masks (70%), but only 26% of the farmers used hand gloves in spite of the fact that it is the hands that are usually the most exposed to pesticide residues. All respondents were aware that when they spray pesticides they should avoid eating, drinking and smoking in the field. Nearly all respondents said they normally wash themselves after pesticide spraying, though 42% did not usually change clothes after washing.

Costs and returns of yard-long bean production

Detailed input and output data were collected from each respondent for his or her main field under yard-long bean. Not every respondent was able to provide consistent quantitative data on the monetary costs of all inputs and we therefore used data for only 70 growers in Thailand and 18 growers in Vietnam. We must caution to make inference from the data for Vietnam because of the small sample size.

In Thailand, the average cost of variable inputs was 3,080 USD/ha (Table 5); pesticides accounted for 13% of these. Yard-long bean cultivation mostly relied on own family labor, but some farmers also used hired labor. Average labor use per hectare was 231 person-days. Family labor accounted for 66% of the labor use with the rest hired locally. Farm managers hired both male and female workers, depending on the work to be performed. More male laborers were hired for plowing, operating tractors, irrigating, and pesticide spraying, whereas more female laborers were hired for harvesting, sorting, grading and packaging. Cleaning, sorting, grading, and packing are notably labor intensive activities, as bean pods are sorted one by one according to length, size, maturity, and blemishes. Pods are weighed and packed into plastic bags at 10 kg per pack. It takes about 30 minutes for sorting and grading 50 kg of yard-long bean. Labor costs were converted to value terms using the price of hired labor. The average labor cost, including the opportunity cost of own family labor, was 1,295 USD/ha. Pesticide spraying accounted for about 4% of the total labor use.

In Vietnam, the average cost was substantially higher at 6,266 USD/ha, which reflects the greater land use intensity related to the small average farm size. Although yields are significantly higher than in Thailand, the average selling price was much lower and the difference in gross revenues was therefore less significant than the difference in crop yields. The profit per hectare was USD 2,454 in Vietnam as compared to USD 453 in Thailand. The profit margin—defined as the ratio of net profit and net revenue, was 12.8% in Thailand and 28.1% in Vietnam.

Table 5 Net returns and profits in yard-long bean cultivation in Thailand and Vietnam, 2010

Category	Revenue/cost item [calculation]	Thailand	Vietnam
Revenues	1. Yield (kg/ha)	5,806	25,231
	2. Average price (USD/kg)	0.63	0.35
	3. Gross revenues (USD/ha) [1x2]	3,533	8,720
Costs	4. Variable input cost (USD/ha)	1,246	3,200
	5. Total fixed costs (USD/ha)	540	549
	6. Total labor (USD/ha)	1,295	2,518
	7. Total costs (USD/ha) [4+5+6]	3,080	6,266
Profits	8. Net profit (USD/ha) [3-7]	453	2,454
	9. Net profit margin (USD/ha) [8/3*100]	12.8	28.1

Discussion

In Thailand, farmers have only limited interest in adopting IPM methods because they know very little about these methods and they feel that pesticides provide an effective means of control. For an IPM strategy to succeed, it will be important that these methods do not increase on-farm costs and preferably increase profits. If it is possible to completely eliminate the use of synthetic pesticides, then the cost of an IPM strategy, including the cost of own family labor, should not be more than USD 223/ha per cropping cycle (the amount currently spent on pesticides). Any additional costs need to be offset by short-term yield gains.

These monetary incentives are essential because farmers do not see their use of synthetic pesticides as a problem that needs to be solved. Creating a greater awareness about the risks to which farmers are exposed could benefit IPM adoption but only in the long-term. Small improvements in current pesticide handling practices, such as regarding the use of protective gear and the mixing of pesticides, could make a relatively large contribution to human health. An IPM training program can build on the fact that farmers are literate, have long experience in yard-long bean growing (18 years on average), and like to experiment on their farms as indicated by frequent changes in cultivar selection and a broad willingness to try IPM methods if provided to them.

In Vietnam, yard-long bean is grown on extremely small plots (750 m^2 on average). This poses a challenge in the introduction of IPM methods based on natural enemies because the continued use of broad-spectrum insecticides on other crops in neighboring plots would reduce the population of natural enemies. Use of pheromone traps as a monitoring or mass-trapping tool is also not effective, unless it is practiced at community level. A further challenge lies in the fact that most yard-long bean growers appear to be very satisfied with the synthetic pesticides they currently use.

An IPM training program in Vietnam can build on the fact that farmers have a long experience in yard-long bean growing and show great interest in trying IPM methods on their farm. Most farmers have contacts with the government extension system, though private shopkeepers and pesticide traders are also influential in farmers' pest management decision-making. There is a distinct gender pattern in yard-long bean cultivation activities with men doing most of the spraying and women doing most of the daily management; both men and women will therefore need to be involved in an IPM training program.

Conclusion

A wide range of arthropod pests and plant diseases affect yard-long bean production in Thailand and Vietnam but *M. vitrata* is by far the most significant problem. Farmers almost entirely rely on synthetic pesticide use in managing pests and have only limited knowledge of alternative methods. Most yard-long bean growers are satisfied with the level of control offered by synthetic pesticides and feel it improves the marketability of their crop and the price they receive. Together with the very small-scale of production systems, these pose serious challenges to the introduction of IPM methods. An IPM strategy needs to let farmers experiment with IPM methods on their farm while simultaneously raising their awareness about the risk of pesticides to the health of their families, consumers, and the environment.

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