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Publisher: Taylor & Francis

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International Journal of Pest Management

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/ttpm20>

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Available online: 16 May 2012

To cite this article: H. Berg & N.T. Tam (2012): Use of pesticides and attitude to pest management strategies among rice and rice-fish farmers in the Mekong Delta, Vietnam, International Journal of Pest Management, 58:2, 153-164

To link to this article: <http://dx.doi.org/10.1080/09670874.2012.672776>

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Use of pesticides and attitude to pest management strategies among rice and rice-fish farmers in the Mekong Delta, Vietnam

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(Received 16 August 2011; final version received 29 February 2012)

This study assesses the use of pesticides and attitude to pest management strategies among rice and rice-fish farmers in Cần Thơ and Tiền Giang provinces of the Mekong Delta, Vietnam, in 2007. A comparison is made to a similar study in 1999, in order to identify changes in patterns of pesticide use and possible influences of integrated pest management (IPM) programmes and brown planthopper (a major pest) outbreaks. One hundred and twenty farmers used 66 different pesticides, similar to the 64 pesticides recorded as being used in the 1999 survey. Nine of the 10 most popular pesticides in 2007 were the same as those found to be popular in 1999. Insecticides are used by 73–95% of the farmers, which is the most commonly employed type of pesticide. The number of applications of both herbicides and fungicides has more than halved since 1999 for all farmers, while insecticide applications has doubled for IPM farmers (those with prior training in IPM methodology). Similarly, the average dose of active ingredient (a.i.) of insecticides per crop has decreased slightly for non-IPM rice farmers, while it has more than doubled among IPM farmers, resulting in almost the same amount of a.i. per crop for all groups of farmers (insecticides 0.6, fungicides 0.5, and herbicides 0.3 kg a.i. ha⁻¹ crop⁻¹). Overall, the results indicate a temporal trend for more selective use of pesticides and an increased awareness among non-IPM farmers of the negative side effects of pesticide use.

Keywords: agro-ecosystem; IPM; Mekong Delta; pesticides; rice-fish farming

1. Introduction

The Mekong Delta of Vietnam is one of the most important rice-producing areas of the region and plays an important role in providing export revenues and meeting future food demands. Strategies for increased agriculture production have mainly focused on intensified rice farming, with high-yielding rice varieties and increased use of agrochemicals (UNEP 2005; Huan et al. 2008; Phong et al. 2010).

The intensification of agricultural production in the Delta has not been achieved without drawbacks. Increased reliance on pesticides has proved to be unsustainable and cost-inefficient due to the negative effects of pesticides on human health and the environment (Pingali and Gerpacio 1997; Berg 2002; UNEP 2005; Dasgupta et al. 2007; Escalada et al. 2009a). Pesticides are still the main pest control method used by farmers, and a large proportion of their sprays are misused because of poor knowledge and uninformed decisions (Dasgupta et al. 2007; Huan et al. 2008; Escalada et al. 2009a). Over-use of fertilisers has sometimes also led to high pest and disease infestations, promoting in turn higher usage of pesticides (Huan et al. 2005; Sebesvari et al. 2011; Bottrell and Schoenly 2012). Recent studies show, however, that farmers' attitudes and pest-management strategies in the Delta can be modified through information

campaigns and participatory field experiments (Huan et al. 2005, 2008), resulting in substantial reductions in pesticide use (Escalada et al. 2009a). Integrated pest management (IPM) programmes have also helped to develop ecologically-based pest control methods and improved rice-farming systems, which are not only higher-yielding but also more sustainable (Huan et al. 1999; Escalada et al. 2009a). In addition, the Vietnamese Government is promoting diversification of agriculture and intensification of aquaculture (Nhan et al. 2007; Phong et al. 2010), and rice-fish farming provides a promising opportunity to further develop ecologically sound management strategies of the rice field environment (Dela Cruz 1994; Halwarth 1998; Berg 2002; Xie et al. 2011).

This study assesses the use of pesticides and the attitude to pest management strategies among IPM and non-IPM rice and rice-fish farmers in Cần Thơ and Tiền Giang provinces in 2007, and to what extent these factors have changed since 1999, when a similar survey was conducted in the same provinces (Berg 2001, 2002). During the intervening period, the Delta was affected by severe outbreaks of brown planthopper (*Nilaparvata lugens* (Stål), known as BPH) and virulent diseases (Sebesvari et al. 2011; Escalada et al. 2009b). Information campaigns and participatory field experiments to encourage rice farmers to reduce their use of

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pesticides were conducted in the two provinces in 2002 (Huan et al. 2005); and in 2004 (Huan et al. 2008). It is intended that the current study will provide insights into the long-term impact of these and similar information campaigns, and into the extent to which farmers are willing to transform current rice-farming practice into more sustainable farming strategies.

2. Methods

2.1. Study area

The Vietnamese Mekong Delta covers an area of 40,000 km², and is the most important agricultural region of Vietnam (Figure 1). Covering only 12% of Vietnam's total land area, it supplies more than half of the national rice output and provides 90% of Vietnam's rice exports (General Statistics Office 2009; Johnston et al. 2009). Rice yields are the highest in the region, with up to 15 metric tons per hectare per year (Cau 2011). The climate is characterised as tropical semi-equatorial with a mean temperature of 27°C. The mean annual rainfall is 1600 mm, with approximately 90% of the rain comes during the rainy season in May to October (General Statistics Office 2009).

Large areas of the Mekong Delta are suitable for freshwater aquaculture, but only minor areas have been used for this purpose (Nhan et al. 2007). However, aquaculture is currently expanding in terms of areas and raising methods, mostly through shifting

from one-crop wet paddy cultivation (Nhan et al. 2007; General Statistics Office 2007).

Field surveys were conducted in Cần Thơ and Tiền Giang provinces, which represent major rice-producing regions of the Mekong Delta (Table 1, Figure 1). The districts of Go Cong Tay and Cai Be represent two different rice-producing areas within Tiền Giang. The area around Cai Be has a very good irrigation system consisting of a network of many canals and natural rivers. The first rice crop is usually grown from November to February, the second from February to May, and the third from May to August. Go Cong Tay has a much poorer irrigation system as compared to the Cai Be province. The first rice crop is grown from November to January, the second from May to August, and the third from September to November.

The O Mon and Co Do district, which lies in the Cần Thơ province, is also representative of the irrigated rice areas of the Mekong Delta, both in aspects of physical environment and productivity. Rice is cultivated in the dry and wet season using the double rice-cropping system and in the dry, spring-summer and wet season using the triple rice-cropping system.

2.2. Field survey

In total, 120 farmers were interviewed in Cần Thơ and Tiền Giang provinces in 2007. The farmers were categorised into four groups: farmers cultivating only rice (R), farmers cultivating rice and farming fish (RF),

Figure 1. (Colour online) Cần Thơ and Tiền Giang are major rice producing provinces in the Mekong Delta.

farmers cultivating rice and farming fish using IPM (RFIPM), and IPM farmers cultivating only rice (RIPM). IPM farmers were defined as farmers who had attended some form of training in IPM methodology. Each group in each province consisted of approximately 15 farmers. As only a minority of the farmers employ rice-fish farming, these groups were overrepresented in the study. Interviews were made with farmers who had two or three rice crops per year, as these were the systems with the highest use of pesticides. To be able to make a comparison over time, the same questionnaires were used as in a similar study from 1999 (cf. Berg 2001). As it was not possible to find all farmers interviewed in 1999, it was decided to focus primarily on the same districts.

When completed, the questionnaires were checked and translated into English. The data were analysed by

Table 1. Some characteristics of Tiền Giang and Cần Thơ provinces of Vietnam in 2007 (General Statistics Office 2007, 2009).

	Tiền Giang	Cần Thơ
Area of province (km ²)	2484.2	1401.6
Population size (thousands)	1726	1159
Population density (individuals/km ²)	701	836
Planted area of paddy by province (ha, thousands)	247	208
Production of paddy by province (tons, thousands)	1307	1131
Area of water surface for aquaculture by province (ha, thousands)	13	14
Production of farmed aquatic product by province (tons, thousands)	77.5	150.9

dividing the farmers into the four different categories (R, RF, RFIPM, RIPM) in each district. As the answers between farmers from the different districts were often similar, they were pooled into the same category. Differences between categories were investigated using one-way analysis of variance (ANOVA) with Tukey's HSD (honestly significant difference) used as the post-ANOVA test.

3. Results

3.1. Farming attributes

The average age of farmers ranged from 46 to 51 years (Table 2). The educational level was about 8 years, which is higher than that recorded in 1999 for non-IPM farmers. The average household size was 5 persons, which is a slight decrease as compared to 6 persons recorded in 1999 (Berg 2002). Farmers in all groups had more than 20 years experience of rice farming, while experience of rice-fish farming was approximately 5 years. The farm size remains small (around 1 ha), which is attributable to the Vietnam Government's land tenure policy (Escalada et al. 2009a). Most farmers own their farms. Average rice yield per crop was 5.7 metric tons per hectare, which is a significant increase from the average of 4.6 metric tons in 1999, and similar to the findings of Escalada et al. (2009a) and Cau (2011).

3.2. Pesticide use patterns

Among the 120 farmers, a total of 66 different pesticides were found to be used, which is a very similar figure (64) to the 120 farmers surveyed in 1999 (Table 3). The number of different insecticides used has

Table 2. Household composition, farm size, rice yield and experience of rice and rice-fish farming among farmers in Cần Thơ and Tiền Giang provinces in 2007.^a

		Type of farmer ^b			
		R	RF	RFIPM	RIPM
Age of farm owners (years)	Mean	49.8	50.3	50.5	46.8
	SD	10.1	8.8	9.1	8.4
Household size	Mean	5.3	4.8	5.2	4.9
	SD	1.7	1.1	1.6	1.5
No. of individuals involved in rice-farming	Mean	2.9	3.1	3.3	2.8
	SD	1.0	1.3	1.4	1.1
Educational level (years)	Mean	8.0	8.7	8.7	8.6
	SD	2.0	1.8	2.7	2.6
Total farm area (ha)	Mean	1.0 ^a	1.2 ^b	1.1 ^{ab}	1.0 ^a
	SD	0.6	0.7	0.5	0.6
Rice yield (kg ha ⁻¹ crop ⁻¹)	Mean	5732	5744	5327	5710
	SD	1279	1319	1105	1544
Experience in rice farming (years)	Mean	25.9 ^a	22.7 ^b	25.3 ^a	23.6 ^{ab}
	SD	8.6	9.1	12.3	9.3
Experience in rice-fish farming (years)	Mean	—	5.0	4.8	—
	SD	—	2.9	2.8	—

^aMeans that do not share the same superscript letter are significantly different ($P < 0.05$).

^bKey: R, farmers cultivating only rice; RF, farmers cultivating rice and farming fish; RFIPM, farmers using IPM, cultivating rice and farming fish; RIPM, farmers using IPM, cultivating only rice.

Table 3. The 20 pesticides most commonly used by rice farmers and rice-fish farmers in Tiền Giang and Cần Thơ provinces in 2007.

Pesticides*	Pesticide formula	Active ingredient	% farmers using	WHO classification ^c
Fungicides (10)				
	Anvil ^{a,b}	Hexaconazol	11.6	III
	Tilt ^{a,b}	Propiconazol	8.2	II
	Fuji-one ^{a,b}	Isoprothiolane	2.2	II
	Validacin ^{a,b}	Validamycin A	2.2	U
	Beam	Tricyclazole	1.4	II
	Fuan	Isoprothiolane	1.2	II
Herbicides (7)				
	Sofit ^{a,b}	Pretilachlor + fenclorim	8.2	U
	Meco	Butachlor	4.1	III
	Turbo	Glyphosate	0.7	III
Insecticides (49)				
	Bassa ^{a,b}	Fenobucarb	14.7	II
	Actara	Thiamethoxam	6.5	n.a
	Applaud ^b	Buprofezin	5.6	III
	Padan ^{a,b}	Cartap hydrochloride	3.9	II
	Regent ^b	Fipronil	3.6	II
	Fastac ^{a,b}	Alpha-cypermethrin	3.1	II
	Mipsin	Isoprocarb	1.4	II
	Tungcydan	Chlorpyrifos Ethyl + Cypermethrin	1.2	II
	Trebon ^b	Etofenprox	1.2	U
	Methink	Quinalphos	1	II
	Hopsan	Fenobucarb + Phenthoate	1	II
Others			17	
Total (66)			100	

*Figures in parentheses denote the total number of pesticides recorded.

^aAlso found among the 20 most commonly used pesticides in Long An province in 1997 (Ha 1997).

^bAlso found among the 20 most commonly used pesticides in Tiền Giang and Cần Thơ provinces in 1999 (Berg, 2001).

^cWHO classification: II – moderately hazardous; III – slightly hazardous; U – unlikely to present acute hazard in normal use (WHO 2009).
n.a., not available

increased by 50% since 1999, and constitutes almost 75% of the identified pesticides in 2007. The number of herbicides and fungicides used has decreased by 50% and 40%, respectively (cf. Berg 2001). Although the overall proportion of insecticides, herbicides and fungicides has changed, 9 of the 10 most popular pesticides used in 2007 are the same as those among the 10 recorded as most popular in 1999, and together are used by 65% of the farmers (Table 3). This indicates a fairly conservative use of pesticides among farmers, considering that most pesticides are freely available on the market and that the number of registered active ingredients used for pesticides in Vietnam has increased from around 200 in 1997 to 650 in 2008 (MARD 1997–2008).

Similarly to 1999, the most commonly used pesticide in 2007 was the insecticide Bassa (often used against plant hoppers) followed by the two fungicides Anvil and Tilt, and the herbicide Sofit (Table 3). Many of the different insecticides recorded as being used were only employed by small groups of farmers. The high diversity of insecticides used could be due to problems posed by pesticide resistance in insects (Table 4, point 19), which also is indicated by the fact that many farmers, especially in Tiền Giang, complained about the low quality of insecticides (Table 4, point 4).

The majority of the farmers saw insects as the most problematic type of pest (Table 4, point 20) and

insecticide application was the most common control method among non-IPM farmers, while IPM farmers incorporated pesticide application as part of an IPM strategy (Table 4, point 1).

An increased proportion of non-IPM farmers has learnt how to use pesticides from plant protection staff, whom they meet almost as frequently (3 times/year) as IPM farmers (Table 4, points 2 and 3). This is a significant improvement compared to the situation in 1999, especially for non-IPM rice-fish farmers, who in many cases seemed to be as “well informed” as IPM farmers. Although only 10% of the farmers stated that they had learned to use pesticides from television and radio broadcasts, this was an increase compared to 1999 and has probably helped to reach a broader group of farmers.

The majority (60%) of the farmers decided to employ spraying of pesticides on the basis of field survey results, informing them of the amount of pest infestation on the crop, and they selected pesticides that only kill the target pest (Table 4, points 14 and 15). This indicates a more selective use of pesticides among farmers in 2007 compared with 1999, when most non-IPM farmers relied on scheduled sprays.

On average each farmer uses two different kinds of insecticides, which is twice the amount used by IPM farmers in 1999, but similar to the number of insecticides used by non-IPM farmers in 1999

Table 4. Answers (% of farmers) relating to pesticides and pest management strategies among rice farmers and rice-fish farmers in the Mekong Delta, 2007.

	Type of farmer ^a			
	R	RF	RFIPM	RIPM
1 Which methods do you use to control pests?				
pesticide	90.9	72.7	52.8	26.9
IPM	—	—	38.9	61.5
resistant rice varieties	9.1	27.2	8.3	11.5
2 Where did you learn how to use the pesticide?				
from plant protection staff	26.6	60.0	41.2	49.0
from other farmers & own experiment	48.1	20.0	27.9	38.8
from pesticide shop/reseller	12.7	10.0	20.6	8.2
radio/TV	12.7	10.0	10.3	4.1
3 How often do you see plant protection staff (times/year)?				
average	2.7	3.1	2.9	3.7
SD	2.1	1.7	1.1	1.8
4 Problems related to pesticides that you think are important?				
cost of pesticide	13.6	27.3	3.4	18.2
health effects	18.2	18.2	20.7	18.2
environment effects	4.5	18.2	31.0	18.2
quality/pest resistant	63.6	36.4	44.8	45.5
5 Have the pesticides been a problem for your health?				
no	5.9	4.0	11.4	3.8
yes	94.1	96.0	88.6	96.2
6 Kind of health problem from pesticide-spraying?				
tired	64.7	62.5	42.1	74.2
shock	8.8	9.4	23.7	0.0
headache	8.8	15.6	7.9	12.9
feel dizzy	8.8	6.3	13.2	6.5
hot and itchy	2.9	3.1	2.6	3.2
no	5.9	3.1	10.5	3.2
7 Do you use any protection when spraying?				
mask	70.8	45.1	84.6	82.1
protective clothes	25.0	51.0	7.7	10.7
eyeglasses	4.2	0.0	2.6	3.6
no	0.0	3.9	5.1	3.6
8 Do you think pesticides can have a negative effect on the yield from your field?				
yes	42.3	100.0	96.6	69.2
no	0.0	0.0	3.4	19.2
don't know	57.7	0.0	0.0	11.5
If yes, why?				
natural feed for the fish decrease	—	53.8	81.3	40.0
fish growth decrease	—	38.5	18.8	20.0
kills natural enemies to pest	—	7.7	0.0	40.0
9 Have fish catches in the rice field changed during the past 3 years?				
decrease	—	62.5	28.0	—
increase	—	18.8	56.0	—
don't know	—	18.8	16.0	—
10 If they decreased, what is the main reason?				
pesticides	—	53.3	60.0	—
low water	—	6.7	10.0	—
don't know	—	40.0	30.0	—
11 Do you know of any natural enemies of pests in your field?				
yes	56.7	65.4	97.2	100.0
no	43.3	34.6	2.8	0.0
12 What effect can pesticides have on natural enemies of pests?				
kill natural enemies to pests	84.8	81.5	78.9	100.0
no effect	12.1	11.1	13.2	0.0
no idea	3.0	7.4	7.9	0.0
13 Do you think pesticides can increase pest problems in your field?				
yes	52.0	100.0	100.0	88.0
no	20.0	0.0	0.0	4.0
don't know	28.0	0.0	0.0	8.0
14 How do you decide to spray?				
according to other farmers (1)	10.6	9.7	1.8	3.0
according to field survey (2)	61.7	61.3	54.4	63.6
combination of 1 & 2	8.5	12.9	17.5	6.1
scheduled sprays	2.1	3.2	7.0	3.0
other	17.0	12.9	19.3	24.2

(continued)

Table 4. (Continued).

		Type of farmer ^a			
		R	RF	RFIPM	RIPM
15	How do you select a pesticide for pest control?				
	pesticide that can kill all pest	39.5	11.1	11.1	20.0
	pesticide that kill only target pest	47.4	74.1	80.6	76.0
	according to other farmers	10.5	7.4	0.0	0.0
	other	2.6	7.4	8.3	4.0
16	Do you make any changes in the rice field before applying pesticides?				
	increase water level	17.9	5.3	12.0	25.0
	decrease water level	35.7	84.2	84.0	50.0
	no	46.4	10.5	4.0	25.0
17	Have you changed your use of pesticides during the past 3 years?				
	% change	10.4	3.8	−18.3	−24.4
	SD	22.1	33.0	26.9	36.0
18	Which pesticides have increased/decreased most?				
	fungicides	13.7	7.7	37.8	5.0
	herbicides	23.7	23.1	31.1	15.0
	insecticides (mostly increase)	63.2	69.2	28.9	70.0
	don't know	0.0	0.0	2.2	10.0
19	Why did you change your use of pesticides?				
	Increase because:				
	avoid resistant pests	16.7	76.9	85.7	33.3
	increased number of pests	83.3	23.1	14.3	66.7
20	Which are the most problematic pests?				
	insects	70.8	82.4	66.7	75.9
	diseases/fungi	27.1	11.8	31.0	20.7
	weeds	2.1	5.9	2.4	3.4
21	Would you like to start with IPM				
	yes	52.2	88.5	—	—
	no	47.8	11.5	—	—
22	Reason for implementing IPM?				
	lower cost	—	—	62.0	65.7
	protect health	—	—	10.0	25.7
	protect the environment	—	—	18.0	0.0
	decrease pesticide use	—	—	10.0	8.6
23	Has IPM changed your income?				
	Increase				
	average	—	—	20.4	8.1
	SD	—	—	10.0	2.8
24	Has rice-fish farming changed your income?				
	Increase				
	average	—	20.3	26.6	—
	SD	—	13.3	15.5	—

IPM, integrated pest management; SD, standard deviation.

^aFor key, see Table 2 and text.

(Figure 2). The number of different fungicides and herbicides used has halved for all groups of farmers, and overall there has been a decrease in the total number of pesticides used (Figure 2).

There has been a general decrease in the percentage farmers using pesticides, especially fungicides and herbicides (Figure 3). However, more IPM farmers use insecticides in 2007 as compared to 1999 (Figure 3). Overall, pesticides are more commonly used among non-IPM farmers as compared to IPM farmers (Figure 3).

The average number of applications of fungicides has decreased by 70% since 1999 for all farmers, while herbicide applications remain similar to those of 1999 (Table 5). The number of insecticide applications has doubled for IPM farmers, but halved for non-IPM farmers, resulting in approximately the same number of total applications (2.6–3.0) per crop for all group of farmers in 2007 (Table 5). Similarly,

Figure 2. Average number of different pesticides, used per farmer in Tiền Giang and Cần Thơ in 2007 and in 1999 (Berg 2001). Key: R, farmers cultivating only rice; RF, farmers cultivating rice and farming fish; RFIPM, farmers using IPM, cultivating rice and farming fish; RIPM, farmers using IPM, cultivating only rice.

the average dose of active ingredient of insecticides per crop has decreased slightly among non-IPM rice farmers, while it has increased significantly among IPM farmers, resulting in almost the same amount active ingredient per crop for all four farmer's groups

(Table 6). This result is somewhat contradictory to the farmers' own perceptions, where IPM farmers estimate there to have been an overall decrease in their use of pesticides while non-IPM farmers estimate there to have been a small increase (mainly

Figure 3. Percentage of farmers spraying their crops with herbicides, fungicides and insecticides in Tiền Giang and Cần Thơ in 2007 and in 1999 (Berg 2001). For key, see text and Figure 2.

Table 5. Average number of pesticide applications (per rice field) on the first crop among rice (R) and rice-fish farmers (RF) in Tiền Giang and Cần Thơ provinces in the Mekong Delta in 1999 and 2007.

		2007				1999			
		R	RF	RFIPM	RIPM	R	RF	RFIPM	RIPM
Fungicides	Average	0.9 ^a	0.7 ^a	0.7 ^a	0.8 ^a	3.2 ^c	2.1 ^b	1.8 ^b	2.5 ^{bc}
	SD	0.7	0.6	0.7	0.8	1.4	1.7	1.1	1.8
Herbicides	Average	0.7	0.7	0.5	0.7	0.9	0.8	0.7	0.6
	SD	0.6	0.8	0.6	0.8	0.6	0.7	0.8	0.5
Insecticides	Average	1.4 ^a	1.6 ^a	1.4 ^a	1.2 ^a	3.1 ^b	3.2 ^b	0.6 ^a	0.6 ^a
	SD	0.6	1.2	1.2	0.6	1.5	2.0	0.8	0.9
Total	Average	3.0 ^a	3.0 ^a	2.6 ^a	2.7 ^a	7.2 ^b	6.1 ^b	3.1 ^a	3.7 ^a
	SD	1.2	1.2	1.4	0.9	2.3	2.7	1.4	1.7

Means that do not share the same superscript letter are significantly different ($P < 0.05$). Different pesticides applied concurrently were counted as different applications.

IPM, integrated pest management; SD, standard deviation.

Table 6. Average dose (kg a.i.ha⁻¹ crop⁻¹) of pesticides among rice (R) and rice-fish farmers (RF) in Tiền Giang and Cần Thơ provinces in the Mekong Delta in 1999 and 2007.

		2007				1999			
		R	RF	RFIPM	RIPM	R	RF	RFIPM	RIPM
Fungicides	Average	0.48	0.35	0.48	0.52	0.55	0.29	0.27	0.26
	SD	0.57	0.51	0.62	0.67	0.55	0.45	0.45	0.40
Herbicides	Average	0.27	0.28	0.16	0.28	0.31	0.20	0.17	0.14
	SD	0.41	0.56	0.32	0.58	0.27	0.26	0.30	0.22
Insecticides	Average	0.77 ^a	0.60 ^{ab}	0.65 ^{ab}	0.46 ^{bc}	0.93 ^a	0.52 ^{abc}	0.13 ^c	0.20 ^c
	SD	0.74	0.50	0.52	0.51	1.16	0.53	0.33	0.50
Total	Average	1.52 ^a	1.24 ^a	1.30 ^a	1.27 ^a	1.80 ^a	1.01 ^a	0.57 ^b	0.60 ^b
	SD	1.05	0.96	0.81	0.85	1.22	0.75	0.58	0.66

Means that do not share the same superscript letter are significantly different ($P < 0.05$).

IPM, integrated pest management; SD, standard deviation.

in insecticides) during the last three years (Table 4, points 17 and 18).

3.3. Perceptions of pesticide impacts

Almost all farmers reported that they have experienced negative health effects from using pesticides (Table 4, point 5). Most farmers suffer fatigue after spraying pesticides and many develop a headache and experience dizziness (Table 4, point 6); these are well-known neurological symptoms of cholinesterase inhibition (Dasgupta et al. 2007). Some farmers also feel “hot and itchy” and “shocked” after spraying (Table 4, point 6). The insecticides Bassa and Padan were commonly mentioned as the most problematic pesticides; both are classified as moderately hazardous by the World Health Organization (WHO 2009; Table 3).

The proportion of farmers reporting adverse health effects and the variety of symptoms reported have increased since 1999, despite the fact that the use of protective measures has increased (Dasgupta et al. 2007). In 1999 less than 50% of the farmers protected themselves when spraying, and then with a mask only. In 2007 almost all farmers used at least one form of protection, including mask, protective clothes and eyeglasses (Table 4, point 7).

All farmers (albeit non-IPM rice farmers to a lesser degree) are concerned about the environmental effects of pesticides (Table 4, point 4). Many rice-fish farmers refer to the potential effects on fish, and almost all rice-fish farmers were of the opinion that pesticides can decrease the overall yield obtainable from their fields through a decrease in the amount of natural food for fish and a decrease in fish growth (Table 4, point 8). This perception is much stronger than it was in 1999, and overall it seems that all farmers, and especially non-IPM rice-fish farmers, are more aware of the

potential environment and health effects from pesticides (Table 4, points 4, 5, 8, 12–15; Figure 4).

3.4. IPM and integrated rice-fish farming

Rice-fish farmers estimated an average decrease of around 10% in fish yields during the last three years before 2007 and the majority of the farmers thought this was due to the high use of pesticides (Table 4, point 9, 10). This could explain why the majority of the non-IPM rice-fish farmers would prefer to start with IPM (Table 4, point 21). With potential negative effects of pesticides on fish, IPM may provide the means of both reducing the use of pesticides and of optimising the combined production of both rice and fish.

An economic comparison between costs and income among the different groups of farmers shows that rice-fish farming provides a competitive alternative to rice mono-cropping (Table 7). The rice yields are similar among the different groups of farmers (Table 2), although non-IPM farmers use significantly more seeds (Table 7). The additional yield of fish, which is mostly sold, results in a higher gross income for rice-fish farmers as compared to rice farmers (Table 7). Compared with rice farmers, the rice-fish farmers spend less money on pesticides, but more money on fertilisers, fish juveniles (fingerlings) and fish feed (Table 7).

More farmers were interested to take up IPM in 2007 as compared to 1999, indicating an overall increased awareness among farmers about the benefits from IPM and negative effects from pesticides (cf. Figure 4). The main reason to start with IPM is to reduce costs, but the protection of both health and the environment is also seen as important (Table 4, point 22).

Figure 4. Farmers attitudes to pesticides in Tiền Giang and Cần Thơ in 2007 and in 1999 (Berg 2001). For key, see text and Figure 2.

Table 7. Annual costs and benefits (Million VND ha⁻¹ year⁻¹) in rice monoculture and rice-fish farming among farmers with three crops in Tiền Giang and Cần Thơ provinces in the Mekong Delta, 2007.

			R	RF	RFIPM	RIPM
Costs	Rice crop					
	Seed	Mean	1.917 ^a	1.821 ^{ab}	1.557 ^b	1.537 ^b
		SD	0.450	0.695	0.440	0.303
	Fertiliser	Mean	5.371 ^a	6.839 ^a	7.982 ^b	7.396 ^b
		SD	2.098	2.018	2.885	2.537
	Pesticides	Mean	2.006	1.650	1.370	1.857
		SD	0.973	1.254	0.850	1.040
	Labour	Mean	8.036 ^{ab}	6.061 ^{ab}	8.840 ^a	5.732 ^b
		SD	4.595	3.212	4.367	2.397
	Fish					
	Fingerlings	Mean	–	1.133	1.412	–
		SD	–	0.689	0.785	–
Total cost	Fishfeed	Mean	–	0.940	1.067	–
		SD	–	0.523	0.622	–
		Mean	17.320 ^a	18.444 ^a	22.229 ^b	16.522 ^a
		SD	4.984	3.560	4.320	3.238
Income						
	Rice crop	Mean	53.155	53.499	49.544	53.105
		SD	6.752	8.458	7.524	7.001
	Cultured fish	Mean	–	4.665	7.985	–
		SD	–	3.749	6.330	–
	Wild species	Mean	–	0.244	0.450	–
		SD	–	0.184	0.583	–
		Mean	53.155	58.408	57.979	53.105
Total income		SD	6.752	7.915	9.247	7.001
Net income		Mean	35.826	39.964	35.750	36.584
		SD	7.799	9.059	10.532	7.127

Means that do not share the same superscript letter are significantly different ($P < 0.05$).

Compared with 1999 an increased number of farmers show awareness of the importance of natural enemies in rice pest management (Table 4, point 11; Figure 4). Commonly-mentioned enemies include fish, spiders, ants and dragonflies. Significantly more farmers, especially non-IPM farmers, stated that they considered pesticides to kill natural enemies to pests and thus to increase pest problems in the field (Table 4, points 12 and 13; Figure 4).

Overall the results indicate a more selective use of pesticides and an increased awareness of the negative side effects of pesticides among the farmers, and especially among non-IPM rice-fish farmers, in 2007 compared with 1999 (Figure 4).

4. Discussion

4.1. Pesticide use pattern

Both the increased number of different insecticides used in 2007 as compared to 1999, and the complaints about insecticide quality (none were recorded in 1999), indicate that insecticide-resistant insects may have become a more severe problem in 2007 compared with 1999 (Sebesvari et al. 2011). Insects are reported to be the most problematic pest by farmers, and pest outbreaks and increased incidence of resistance among insects would be an expected result of an extended period of insecticide use combined with

an intensification of agricultural production (Wilby and Thomas 2002; Huan et al. 2008; Norton et al. 2010; Sebesvari et al. 2011; Bottrell and Schoenly 2012). Insect outbreaks could also explain the increase in the IPM farmers' doses of insecticides and the number of applications compared with 1999. Escalada et al. (2009a) also found an increased use of insecticides by farmers between 2005 and 2007, and reported that this could be due to major mass media campaigns by pesticide manufactures to promote insecticidal control in rice-farming throughout the Mekong Delta.

Between 2005 and 2008 rice production in the Mekong Delta was affected by severe outbreaks of BPH and virulent diseases. During these years the cultivated areas in Southern Vietnam affected by BPH increased more than three-fold, and by 2008 hundreds of thousands of hectares had been adversely affected (Sebesvari et al. 2011, Escalada et al. 2009b). Outbreaks of BPH were especially severe in provinces with intensive rice production, for example in Dong Thap, An Giang and Tiền Giang. In 2008 more than 50% of the cultivated area in the Dong Thap province was infested by BPH (Sebesvari et al. 2011).

The BPH outbreaks and pesticide advertising motivated officials and farmers to spray insecticides in excess, which disrupted the ecological balance and consequently increased BPH populations (Escalada et al. 2009b). While most plant protection and

extension officers understand that planthopper outbreaks can be induced by insecticide applications, their main recommendation, when an outbreak occurs, is often to use more insecticides (Escalada et al. 2009b).

Considering the BPH outbreaks and intensified rice production during the last decade, the increase in the use of pesticides among non-IPM farmers is surprisingly small. In fact, while the doses used by IPM farmers have increased, non-IPM farmers seem to have adopted a more selective use of pesticides, with almost unchanged doses and fewer applications compared with 1999 (Tables 5 and 6; Figure 3). The main reason for this could be an attempt to reduce costs (cf. Huan et al. 2005). Non-IPM farmers seem to be more aware in 2007, as compared to 1999, that over-use of pesticides can exacerbate pest problems and thus result in a decrease of yield (Figure 4). They increasingly also see the opportunities to reduce the cost of pesticides by a more selective use of pesticides, based on field surveys and by relying on natural control mechanisms in the rice-field ecosystem (Table 4, points 14, 15).

These findings accord with those of Huan et al. (2005, 2008), who reported that “farmers-participatory” experiments in the Delta have helped to improve farmers awareness that a reduction of pesticides can result in higher income, so encouraging farmers to modify their farming practices. IPM farmers estimated that their income had increased by 10–20% after applying IPM (Table 4, point 23), which is probably an overestimate (cf. Huan et al. 2005; cf. Table 7), but is nevertheless indicative of the farmers’ positive experiences of employing IPM.

4.2. IPM and integrated rice-fish farming

Long phases of IPM training, which introduced new strategic approaches to plant protection, have probably helped to influence the perception of millions of farmers, also including farmers not directly involved in IPM training (Huan et al. 2005; Escalada et al. 2009a). This change in perception has been an important step in a transition towards adopting new farming strategies that may provide sustainable alternatives to intensive rice monocropping. However, as pointed out by Escalada et al. (2009a), this transition requires continuous training in IPM, to counterbalance the intensive marketing of pesticides by agrochemical companies.

Our study shows that fish are seen as an important pest control agents by many farmers (cf. Nhan et al. 2007; Xie et al. 2011) and that rice-fish farming could provide a promising opportunity to further develop ecologically sound management strategies for the rice field agroecosystem (Dela Cruz 1994; Halwarth 1998; Berg 2002). Scientific studies, as well as farmers’ experiences, have proved the benefit of rice-fish integration, combining the principles of water conservation, soil improvement and biological control, for

sustainable food production (Mohanty et al. 2004; Vromant and Chau 2005; Xie et al. 2011).

Comparing the total income between the different groups of farmers, rice-fish farming is seen to generate a higher gross income than rice monocropping, a finding consistent with those of previous studies of the benefit of rice-fish farming systems (Berg 2002; Cau 2011; Xie et al. 2011; Table 7). Farmers estimated that rice-fish farming increased their income by 20–25% (Table 4, point 24), which is similar to the findings of Cau (2011).

The comparatively high production costs for rice-fish farming recorded in this study, however, resulted in no significant difference in net income between the different groups of farmers (Table 7). To enable rice-fish farming to become a competitive alternative to rice monocropping, it is critical for the farmer to acquire the technical skills to optimise the natural productivity of an integrated system. Fish-farming makes it possible to both decrease the input of fertilisers and pesticides through, for example enhanced nutrient circulation and natural pest control (Cau 2011; Xie et al. 2011). Over-use of agrochemicals, however, can easily disrupt the ecological balance of an integrated system and result in both increased production costs and suboptimal yields (Berg 2002). From this perspective rice-fish farming and IPM should be seen as complementary strategies which, instead of increasingly relying on pesticides, aim to stimulate natural ecosystem processes for an efficient and long-term production of food (cf. Nhan et al. 2007; Phong et al. 2010; UNEP 2011; Xie et al. 2011).

With convincing evidence of the economic benefits of integrated systems, and means for own experiments and cross-scale learning, different IPM and rice-fish farming projects could help to design and implement future systems that deliver not only food security under increasingly uncertain conditions, but also safeguard biodiversity, ecosystem services and economic security in rural areas.

5. Conclusions

Rapid change and high population pressure in the Mekong Delta makes the development of integrated food production systems based on well-functioning ecosystem services an urgent but complex and challenging task, which must be supported by government policies as well as capacity building for improved farming systems (cf. Nhan et al. 2007; General Statistics Office 2007; Norton et al. 2010).

Although this study indicates an increased awareness of the negative side-effects of pesticide usage, and a more selective use of pesticides among rice-fish and IPM farmers, these findings must be seen in the context of intensified agricultural production and marketing of pesticides, where the “development space” for introducing new, sustainable farming

practices may become increasingly constrained by the demand for increased food production (cf. Norton et al. 2010). This emphasises the urgency to act on existing opportunities. Farming strategies in the Mekong Delta currently seem to encourage more diverse systems. Global awareness of climate change has also brought about an enhanced awareness of the fragility of natural ecosystems and a new, longer-term perspective to national and regional planning, which presents an opportunity to rethink approaches to agricultural production (Johnston et al. 2009; Sebesvari et al. 2011).

Sustained long-term production cannot be achieved through intensified use of pesticides. It must be based on ecological principles, taking advantage of ecosystem biodiversity and productivity (Norton et al. 2010; UNEP 2011). This in turn requires a sound understanding by the local farmer of how to optimize the long-term productivity of the rice field ecosystem. Understanding that pesticides may decrease both the number of natural enemies and the yield of fish is a strong basis for increasingly incorporating the value of biodiversity and ecosystem services in future farming strategies. Government policies promoting integrated systems would further strengthen this perception, which could generate a trend towards more diverse production systems that most likely would be better suited to meet future food demands under increasingly uncertain environment conditions.

Acknowledgements

This study was made with financial support from the Swedish International Development Cooperation Agency (Sida). Practical support was given by a number of institutions in Southern Vietnam. Special thanks are due to Dr Nguyen Thanh Phuong at the Cần Thơ University, Nguyen Minh Thanh at the Research Institute for Aquaculture No. 2, and two anonymous reviewers for providing valuable comments.

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