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9

Are There Productivity Gains from Insecticide Applications in Rice Production?

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Abstract: Insecticides have always been viewed to be necessary inputs to achieve high rice production. However this notion has been challenged by ecologists and economists and they have shown that Asian farmers’ insecticide use has poor or no productivity gains. Farm surveys of more than 5000 households in the Mekong, Vietnam and paired farmer experiments showed that farm yields were not correlated with the number of insecticide sprays used in most cases. In the paired experiments plots there was no significant correlation between yield and number of sprays in both plots. A survey of farms in a rice planthopper outbreak area showed that farms that had applied insecticides in the early crop stages for leaf folder control had higher probability of heavy planthopper attacks or “hopper burn”. The reasons why rice farmers had continued to apply insecticides despite of the poor productivity gain might be due to their misperceptions that lead to overestimate losses caused by insects, the aggressive marketing of pesticides that heightens their loss aversion attitudes thus making them victims of insecticide abuse. Rice farmers appear to be “locked into” circumstances that continue to promote insecticide use despite the lack of productivity gains. With health costs from both acute and chronic long term impacts and environmental costs especially in causing bee and bird mortalities, scientists and policy makers need to rethink future pesticide management strategies to avoid pesticides becoming a threat to food security instead.
Key words: Productivity gains; Externality cost; Insecticides; Yield loss; Marketing regulatory frameworks

9.1 Introduction

Pests have been viewed as major yield constraints to rice production and insecticides as necessary inputs. All the herbivores in rice ecosystems are considered undesirable, damaging and contributing to production loss. This thinking is probably derived from the general agronomic view that any reduction in leaf area will affect photosynthesis and production. There are more than 100 herbivore species that feed on rice, most of them causing slight damages and probably less than 10 species can occasionally capable of causing sufficient economic loss and only when their populations are high. Yield loss estimates from research range from none to 50% depending on the conditions the experiments had been carried out. In 117 experiments conducted over 15 years at the International Rice Research Institute (IRRI), Pathak & Khan (1994) found that field plots "protected from insects" which meant sprayed frequently at weekly intervals yielded almost twice as much as the unprotected plots. The data sets were from experiments done when insecticide sprays in IRRI carried out at weekly intervals and rice was planted asynchronously. From 1993 insecticide use in IRRI farm was systematically reduced and from 2009 insecticide use had reduced by 96% and no significant yield reductions had been reported (Heong et al., 2007). Instead, the biodiversity of all arthropod functional groups such as the herbivores, predators, parasitoids and detritivores, increased significantly. Pesticide use of farm chemical inputs declined between 1993 and 2006. The amount of pesticide active ingredients (ai) used fell from 6.86 to 0.86 kg ai/ha/year, a reduction of 87.5%. The analysis also showed that the main pesticides used were insecticides and these declined from 3.79 kg ai/ha/year in 1993 to 0.16 kg ai/ha/year in 2006, a reduction of 95.8%.

Arthropod biodiversity grouped by guilds in 2005 increased when compared with that of 1989. Species richness of all four guilds was significantly higher. There were twice as many species of herbivores, about 48 more species of predators and parasitoids and greater than 5 times more species of detritivores. There were more species of herbivores such as thrips, plant lice, beetles and hoppers present in 2005, but not in 1989. Since these were minor pests, they probably function more as food for the generalist predators. Predator species were enriched by a greater diversity of generalists such as spiders, hemipterans and beetles. There were more hymenopteran species in 2005 than in 1989, particularly trichogrammatids, mymarids and scelionids. Species richness of detritivores was markedly increased in 2005, especially of dipterans and collembolans. The arthropod composition structure in the two years' samples changed considerably. Proportionately herbivores were more abundant in 1989 (46%) than in 2005 (12%), predators were lower than in 1989, 40% compared to 58%, and detritivores were also lower in 1989, 8% compared with 26%. Parasitoids were, however, slightly higher, 6% in 1989 compared with 4% in 2005. The reduction of insecticides in IRRI farm had contributed significantly to the restoration of arthropod biodiversity as well as the community structure to a more "stable" state (Heong & Schoenly, 1998).

During the Green Revolution of the 1970s and 1980s, insecticides had been introduced into rice production as a necessary input to achieve optimalyields. Prophylactic spraying campaigns were mounted in rice intensification programs like the Masagana 99 in the Philippines and BIMAS in Indonesia (Heong & Schoenly, 1998). Routine spraying programs were also introduced into China, India, Thailand, Bangladesh, Vietnam, Korea and several other Asian countries often with government subsidized pesticides and loan schemes (Conway & Pretty, 1991). The pesticide industry with their aggressive advertising and market schemes played a strong role in encouraging farmers to use pesticides.

This notion that insecticides are always needed for high yields in rice production was challenged by Way & Heong (1994), and they argued that “rice pest management should be based on the contention that insecticides are NOT needed rather than they are and only to be used when pests are ‘guilty’ and only as the last resort”. Economists (Herdt et al., 1984; Antle & Pingali, 1994; Pingali et al., 1997) have also argued that there were hardly any productivity gains from insecticide applications in rice production. When health cost is factored in, it overwhelmed all gains (Pingali et al., 1997). These conclusions were obtained from experiments carried out in the IRRI experimental farm and in researcher-managed farmer plots, where insecticide applications were carefully administered. When they compared (i) fields with no sprays (or natural control), (ii) farmer practice of two routine sprays, (iii) integrated pest management (IPM) using thresholds and (iv) with maximum protection of six sprays, they found that natural control had higher productivity than all the other practices. IPM had the lowest productivity gains when monitoring cost was factored in. Insecticide application efficiency of farmers is generally poorer because their equipment generally has poor spray droplet delivery and farmers often use the wrong types of chemicals and sprayed at the wrong times. An analysis of Philippines farmers’ insecticide sprays showed that 80% of their sprays were misused and unlikely to be effective (Heong et al., 1995). Instead, the insecticide applications of farmers destroy valuable ecosystem services and render the rice crop more vulnerable to secondary pest outbreaks, such as the rice planthoppers (Heong, 2009; Bottrell & Schoenly, 2012). This raises the question “Are there productivity gains by farmers using insecticides?” In this chapter we further explore this question using some farm survey data obtained from the Mekong Delta in Vietnam.

9.2 Insecticide Application: Yield Analyses from 8 Farm Surveys

We used 8 farm survey data sets obtained in three provinces in the Mekong Delta between 2002 and 2012 (Data from Escalada et al., 2009) and explored the relationships between farmers’ insecticide applications and yields. Yields and insecticide applications from a total of 5410 farmers were collected using a standard structured pretested questionnaire. Yields from farms with the number of insecticide applications were computed and compared using ANOVA (Table 9.1). There was no significant difference in farm yields in 5 out of the 8 surveys and 3 had significant difference at 5% level. In the Tien Giang Province 2003 data, yields of farms with 5 and 6 insecticide applications were significantly higher than that with no application. Similarly in the Tien Giang Province 2010 survey, farms with 6 applications had the highest average yield which is significantly higher than farms with 7 applications, but not significantly higher than farms with no applications. In the An Giang Province 2011 data, farms with zero and 6 insecticide applications had higher average yields than farms that had 7 applications.

Table 9.1 Farm insecticide applications and summer-autumn season yields (t/ha) in Tien Giang, Can Tho and An Giang provinces between 2002 and 2012

	Tien Giang				Can Tho		An Giang	
	2003	2004	2010	2011	2002	2003	2011	2012
Sample size	550	630	504	504	788	904	548	550
Mean sprays	3.03	2.13	1.99	1.75	1.62	2.37	3.32	3.19
0 application	4.34	5	7.43	6.4	4.6	6.2	7.43	6.4
1	4.51	5.12	6.69	6.93	4.71	5.76	6.69	6.93
2	4.44	5.08	6.65	6.68	4.67	5.85	6.65	6.68
3	4.49	4.89	6.74	6.83	4.62	5.82	6.74	6.83
4	4.4	5.11	6.58	6.84	4.69	6.09	6.58	6.84
5	5.21	4.84	6.86	6.63	5.06	5.77	6.86	6.63
6	5.04	4.98	8.27	6.75	5.72	6.02	8.27	6.63
7	4.56	5	5.5	6.75	-	5.57	5.5	6.75
8 and more	4.93	4.7	-	-	5.5	5.18	-	8.2
F value	1.99	1.43	2.52	1.7	1.22	1.73	2.52	1.7
Probability	0.03*	0.16ns	0.02*	0.10ns	0.29ns	0.08ns	0.02*	0.10ns

* means significant at p=0.05; ns=not significant

The yield-insecticide application relationships were further explored using regression analyses. Table 9.2 shows regression analyses statistics and the regression coefficients. Three of the 8 data sets had highly significant regression, two had negative coefficients and one was positive. The positive coefficient of 0.123 predicted an average increase of 123 kg of paddy from each insecticide application. Based on the farm gate paddy price of US$ 0.22 per kg and the average cost of an insecticide application of US$ 20, the gain would have been US$ 7 per ha. On the other hand the negative coefficient of 0.135 predicted that there was be a loss of 135 kg or US$ 49 per ha (US$ 29 from paddy loss plus US$ 20 for each application). When labor and health costs were factored in, the gain of US$ 7 per ha in the positive coefficient case would be wiped away and in the negative coefficient case loss would be further exaggerated (loss of > US$ 50 per ha).

Table 9.2 Regression analyses of yield-insecticide application relationships in Tien Giang, Can Tho and An Giang provinces between 2002 and 2012

	F value	Probability	Significance	Regression coeff.
Tien Giang 2003	8.54	< 0.01	Highly significant	0.123
Tien Giang 2004	2.43	0.12	Not significant	– 0.062
Tien Giang 2010	0.04	0.84	Not significant	0.009
Tien Giang 2011	1.35	0.25	Not significant	0.055
Can Tho 2002	4.23	0.04	Not significant	0.073
Can Tho 2003	8.81	< 0.01	Highly significant	– 0.098
An Giang 2011	20.24	< 0.01	Highly significant	– 0.135
An Giang 2012	0.21	0.65	Not significant	– 0.020

The analyses suggested doubtful productivity gains from farmers' insecticide applications. Farmers would be better off if they were to completely avoid insecticides and conserve ecosystem services that will reduce farms' vulnerability to secondary pest outbreaks like the planthoppers that could cause crop failures. The analyses further supports FAO's declaration that "Most tropical rice crops under intensification require NO insecticide use" (FAO, 2011) and Way & Heong's (1994) conclusion that rice pest management should be based on the contention that insecticides are NOT needed and only to be used when pests are "guilty" and only as the last resort.

9.3 Paired Farmer Experiments

During the rice seasons of 2001 and 2002, rice farmers from 35 villages in the Mekong Delta were invited to participate in evaluating practices with reductions in the seed rates for crop establishment, nitrogen rates and insecticide sprays (Huan et al., 2005). This led to the introduction of the "Three Reductions, Three Gains" (Ba Giam Ba Tang in Vietnamese) program supported by the Ministry of Agriculture and Rural Development of Vietnam that spread to all rice growing areas (Huan et al., 2005; Escalada et al., 2010) and had significant impact on farmers' incomes (Huelgas & Templeton, 2010). Volunteer participants divided their fields into two portions and implemented "three reductions" practices by reducing (i) seed rates, (ii) nitrogen rates and (iii) insecticide sprays in one portion (experimental plot). Table 9.3 shows that participating farmers had slightly higher average yields in their experimental plots in both rice seasons. The average difference in yields in the paired plots for the winter-spring (W-S) season was about 0.15 t/ha while in the summer-autumn (S-A) season yield differences were about 0.08 t/ha while insecticide use were reduced by 78% in the W-S season and 77% in the S-A season. Since these were paired experiments in the same fields using the same varieties and basic agronomic practices, except for those introduced in the "three reductions" program, yield differences can be attributed to these practice modifications. Among the three input modifications, insecticide reductions made the highest contribution to the increase in gross margins (Huan et al., 2005). This supports the notion that insecticides are not necessary inputs to secure yields.

Table 9.3 Average yields (t/ha) of farmers' experimental and control plots in paired experiments conducted by volunteers in 2001 and 2002 in the Mekong Delta, Vietnam

Seasons	Sample size	Experimental plots	Control plots
Winter spring 2001-2002	520	6.46	6.30
Summer-autumn 2002	431	4.77	4.69

9.4 Insecticides Increase Vulnerability of Rice Crops to Planthopperpests

A survey of 148 rice farmers in the Mekong Delta, Vietnam where planthopper outbreaks had occurred was conducted. We found that farms that had received insecticide sprays in the early crop stages were 10 times more vulnerable to crop failures caused by severe planthopper attacks known as "hopperburn" (Fig. 9.1). Farms that used insecticides to control leaf folders had higher probability (86%) of "hopperburn" than those that did not (8.1%). Two thirds (66.9%) of the farmers reported hopperburn in their fields and had significantly higher insecticide sprays (4.44 sprays) and lower yields (5.45 t/ha) than those with no hopperburn (1.67 sprays and 6.45 t/ha, respectively). Farms that received their first insecticide sprays in the first 40 DAS (54.7%) were most vulnerable to hopperburn as 91.4% of these farms had hopperburn.

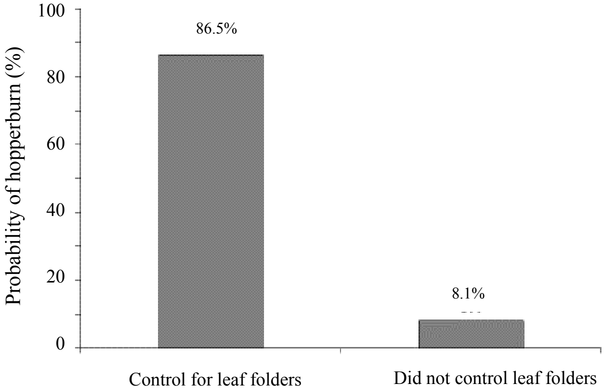

Fig. 9.1 Farms that had sprayed for leaf folders in the early crop season had higher probability to hopper burn than farms that had not sprayed for leaf folders

Those who did spray insecticides in the early crop stages were using insecticides, like pyrethroids, chlorpyrifos and other organophosphates. Most of these insecticides have high toxicity to natural enemies and made crops vulnerable to planthopper outbreaks (Heong & Schoenly, 1998). Leaf damages caused by these pests although highly visible to farmers had negligible impact on yields because of plant compensation (Graf et al., 1992). Ecological research had shown that arthropod food webs start establishing early in the crop seasons and arthropod biodiversity reached the asymptote at about 40 days after crop establishment (Heong et al., 1991). Insecticide sprays at the early crops stages, disrupt the food web structure by reducing the food chain length from 3 to 2 (Cohen et al., 1994) and disorganized the normal predator-prey relationships. Rice fields under such conditions where biological control ecosystem services have been compromised (Heong, 2009) would tend to be more vulnerable to planthopper outbreaks as immigrating adult hoppers would experience lower mortality. Fig. 9.2 illustrates the phenomenon that planthoppers which are typically *r*-strategists (Southwood & Comins, 1976) when released from natural biological control would multiply exponentially to more than a thousand folds as observed by Kenmore et al. (1984).

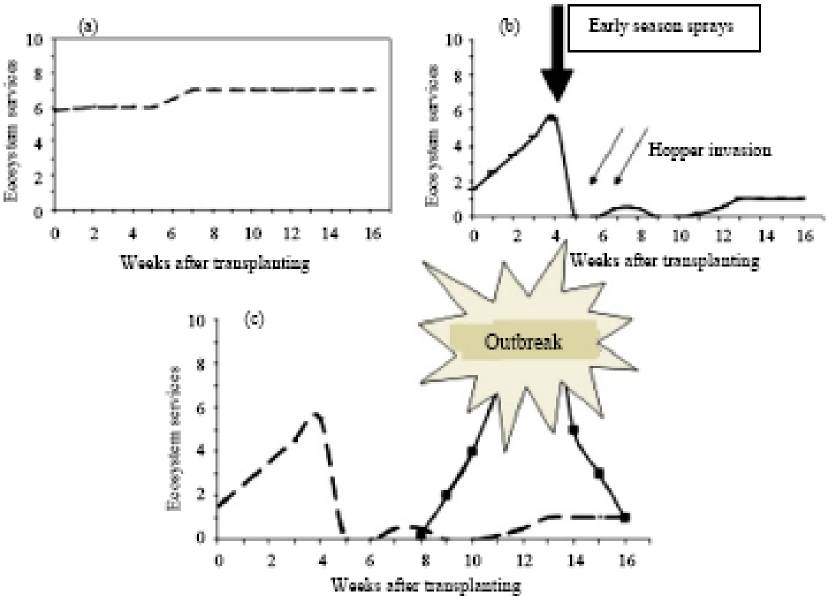

Fig. 9.2 (a) Ecosystem services in rice fields develop normally; (b) When insecticides are sprayed in the early season, ecosystem services are destroyed thus making the fields vulnerable to invading planthoppers; (c) Planthopper populations during the vulnerable period have less constraints and develop into outbreak proportions

9.5 Why Farmers Continue to Spray If There Are No Gains?

Insecticides were packaged into Green Revolution technologies introduced as development assistance programs to Asia in the 1970s and 1980s. Rice farmers were urged to spray their crops once a week (often known as "Monday-Monday" or "Seven-Seven" in the Philippines) in the rice intensification programs (Heong & Schoenly, 1998). In Indonesia the government subsidized 80% of the insecticide cost spending as much as US$ 150 million per year (Gonzales et al., 1993). It was not until 1986 that the subsidies were gradually removed following a presidential decree InPres 3/87 that banned 57 insecticides (Matteson, 2000). Insecticide use in Indonesia dropped primarily because of the subsidy removal resulted in higher costs (Gonzales et al., 1993). IPM was later introduced and millions of farmers were trained to recognize predators and to use insecticide only when necessary. However insecticide use in Indonesia has escalated in the last 10 years (Heong et al., 2013) and this might be in part due to the aggressive marketing strategies of the pesticide industry to sell pesticides as fast moving consumer goods (FMCGs) like tooth paste and soap.

In examining the paradox that despite the lack of productivity gains and externality costs, farmers had continued to use insecticides. Wilson & Tisdell (2001) had referred to this as "locked-in" circumstances farmers seem to face. Farmers also tend to overemphasize the importance of insects, especially the highly visible ones (Bentley, 1989). For instance, leaf damages by leaf folder larvae in the early crop stages with highly visible symptoms and thus high proportion of farmers spray against these leaf feeders (Heong & Escalada, 1997). However these damages inflicted on rice crops at the early stages do not translate into crop loss (Heong, 1990; Litsinger, 1991). Farmers tend to overestimate losses caused by insect by more than 10 folds (Heong & Escalada, 1999). In addition, farmers tend to associate pesticide use with modernism (Kenmore et al., 1985) and thus make them vulnerable victims of pesticide misuse. Furthermore weak pesticide marketing regulatory frameworks had allowed pesticide companies to entrap farmers by pushing sales through aggressive advertising and promotion to create bias in favor of use (Tisdell et al., 1984). Pesticide companies use sales reward incentives such as electrical appliances, holiday trips and even trips to Mecca to push sales. These practices violate FAO's International Code of Conduct for Pesticides Distribution (FAO, 2003) but are rampant especially in countries where the regulatory frameworks for pesticide marketing are lacking or weakly implemented (Heong et al., 2013). Insecticides are being sold as fast moving consumer goods under numerous trade names through multi tier marketing by agents at the village levels in the supply chain. For instance, the insecticide ingredient imidacloprid is sold in more than 500 trade names in China. Such unregulated marketing of pesticides further heightens farmers' loss aversion attitudes and they had become victims to insecticide misuse. In some cases, agricultural extension officials are earning extra cash from chemical companies by promoting the use of their insecticides. In some provinces of China, agricultural extension agents were generating most of their salaries and office operating costs through pesticide sales (Hamburger, 2002) and in Vietnam, extension staff earned extra money by selling inputs to farmers and thus tend to bias the information they provide (McCann, 2005).

At the beginning of the chapter we raised the question "Are there any productivity gains from farmers' insecticide use?" Economists showed that gains from insecticide use in rice production are small and with health and environmental costs factored in most of this is wiped out (Pingali et al., 1997). Insecticides impact human health by acute poisoning after direct exposures that might require immediate medical attention and by chronic health problems caused by sub-lethal doses. As insecticides are neurotoxins they have similar neurotoxic effects on insects, birds, mammals and humans. While the acute toxicity of insecticides on humans are alarming chronic effects of insecticides in low dosages are lesser known. Some recent researches are now linking pesticides that are neurotoxins with Parkinson's and Alzheimer's diseases (Casida & Durkin, 2013), autism, attention deficit hyperactivity disorder (ADHD), and low IQ in children through prenatal exposures (Bouchard et al., 2010). Insecticides are also linked to the decline in bees (Stokstad, 2013) and other non-target species such as birds (Caspar et al., 2014), amphibians, fish, and aquatic arthropods (Van Dijk et al., 2013). The work of Antle & Pingali (1994) discussed the health costs related to direct poisoning cases with less attention paid to long term health effects. Factoring long term health effects will further raise the negative productivity of farmers' insecticide use in rice production. Insecticides may even be a threat to food security. A comprehensive assessment of real productivity gains from farmers' insecticide use is now urgently needed to help scientists and policy makers to rethink and develop pesticide management policies and structures to reduce misuse.

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