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Kong Luen Heong with Larry Wong and Joy Hasmin De los Reyes

No. 27 | August 2013

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The lead author is a principal scientist at the International Rice Research Institute.

Asian Development Bank

Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org

August 2013
Publication Stock No. WPS135985-3

Unless otherwise noted, “$” refers to US dollars.

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Abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
PRC	People’s Republic of China

Executive Summary

Insecticide use was heavily promoted during the first Green Revolution as it promised not only protection from pest attacks but also higher crop yields. Farmers readily embraced this concept and devoted more spending on insecticides as part of their production inputs. Rice planthoppers that were major threats to the Green Revolution have again returned as the most significant pests in most of Asia. In the last 5 years, planthoppers have caused crop losses of more than 10 million tons and have developed resistance to insecticides and new rice varieties.

Rice farmers apply a variety of chemicals collectively called pesticides, to control pests. Insecticides are for insect control; fungicides for disease control; herbicides for weed control; and molluscicides for snail control.

Planthopper outbreaks are induced by insecticides, yet farmers are still encouraged to spray insecticides routinely, especially at the early rice crop stages to protect their rice seedlings from a range of pests of minor importance. To broaden the kill spectrum, insecticide "cocktails" are frequently promoted by local insecticide retailers.

Scientists have shown that planthopper outbreaks can be traced to excessive insecticide use, which is fueled by the promotion of insecticides in the manner of fast-moving consumer goods. Farmers are the main victims in the current poorly regulated pesticide market. A study of the pesticide information supply chain showed that most farmers obtain pest control advice from local retailers rather than extension officials. Retailers adopt market incentives such as credits, raffles, free trips, and gifts to promote sales.

In addition to the health risks posed by using insecticides, farmers unknowingly suffer from hidden additional costs because of the unnecessary spraying. An analysis of farm surveys conducted in the Mekong Delta showed that the relationship between insecticide sprays and rice yields had no significant differences in most cases.

This paper[1] emphasizes the threat of insecticide misuse not only to farmers but, more importantly, also to the sustainable development of rice farming and food security. Thus, it is important to urgently address this threat and to develop more sustainable approaches that will integrate policies, marketing, and technologies to reduce the vulnerability of intensive rice production to planthopper outbreaks. The paper also calls for structural reforms in plant protection services to professionalize plant protection. Ecological engineering methods to increase ecosystem services, for instance, and through conservation of inherent biodiversity may be introduced to enable the reduction of insecticide misuse. The growing of flowers on field bunds, which attracts bees and natural enemies of pests, can be useful to communicate to farmers the value of the bee-like parasitoids that attack pests. New varieties tolerant to pests when grown in ecologically sustainable conditions will be more durable. With structural reforms, other pest management methods such as tolerant varieties, cultural practices, and farmer training programs will have higher impact on productivity.

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[1] This paper was prepared for the Asian Development Bank under TA7493-REG Addressing the Pre- and Post-Harvest Challenges of the Rice Supply Chain by Kong Luen Heong with Larry Wong and Joy Hasmin De los Reyes. The lead author, Kong Luen Heong, is a principal scientist at the International Rice Research Institute (IRRI), fellow of The World Science Academy (TWAS) and the Malaysian Academy of Science. He specializes in pest management research and implementation of integrated pest management and ecological engineering methods for sustainable management of rice pests in Asia. He has authored or coauthored more than 250 scientific papers and three books on pest management in rice. Larry Wong is a program director at the Institute of Strategic and International Studies in Malaysia. He is a development economist by training and has vast operational experience in business and development planning, implementation, and policy analysis. Joy De los Reyes is an assistant manager at IRRI. She is an economist by training and has working knowledge of project evaluation and management.

1. Overview

Preharvest losses caused by pests[1] can threaten rice production, food security, and rural livelihoods. This is especially so when massive pest outbreaks occur at later crop stages. Affected farmers suffer heavy financial losses, fall into debt, and even commit suicide (OAE 2010). Such pest outbreaks can have devastating effects on rice production as rice ecosystems continue to remain vulnerable.

A large variety of chemicals collectively known as pesticides are used by rice farmers in Asia to control pests. Insecticides are used to control insects, fungicides to control diseases, herbicides to control weeds, and molluscicides to control snails.

In many countries, farmers often respond to insect pest threats by increasing insecticide use as prophylactic applications to protect their crops. Oftentimes, the sprays do not work as most farmers tend to overestimate the pest damages and losses, and thus apply more pesticides than necessary. Paradoxically, excessive use of insecticides does not help control pest outbreaks but seems to even induce their numbers. Further, farmers increasingly rely on insecticides that are toxic and have adverse health implications.

This paper examines the link between insecticide use and insect outbreaks, and what this means in terms of maintaining ecosystem services. The paper also asks why there has been a significant use of insecticides, including those that are banned for health reasons, and finally analyzes if there are merits to the use of insecticides in terms of yield improvement. The flow of the paper is as follows: Section 2 discusses the relationship between pest outbreaks and insecticide use. Section 3 presents recent studies on the supply chains of insecticides and pest management information. The section shows how insecticide use by farmers is driven by marketing strategies rather than by the rationale of yield protection. Section 4 briefly examines recent data and arguments of economists that productivity gains from insecticide application are insignificant and are further eroded when externalities such as health and environmental costs are considered. Section 5 summarizes and concludes the discussion with policy options for structural reform to fix insecticide misuse—the root cause of the threats of pest outbreaks in rice production.

2. Planthopper Pest Outbreaks and Insecticide Use

2.1 Planthopper Outbreaks and Crop Losses

Most rice-producing countries in East and Southeast Asia have incurred losses due to rice planthopper outbreaks over the last 10 years. The rice bowl of Thailand in the Central Plains suffered from persistent planthopper outbreaks for 10 consecutive seasons from 2008 to 2012. The Office of Agricultural Economics in the Ministry of Agriculture and Cooperatives of Thailand reported that the outbreaks caused losses worth $52 million or equivalent to about 173,000 tons during the dry season of 2010. In the Mekong Delta of Viet Nam, the loss of around 1 million tons of rice was reported in 2007, which resulted in a government freeze on the export of rice. In Indonesia, rice production in the island of Java lost 0.9 million tons in 2011 due to these pests. Likewise, the People's Republic of China (PRC) lost about 2.5 million tons of rice in 2005 and is

[1] Pests refer to all organisms that can cause economic loss in rice production. These pests include arthropods, pathogens, viruses, weeds, mollusks, and vertebrates.

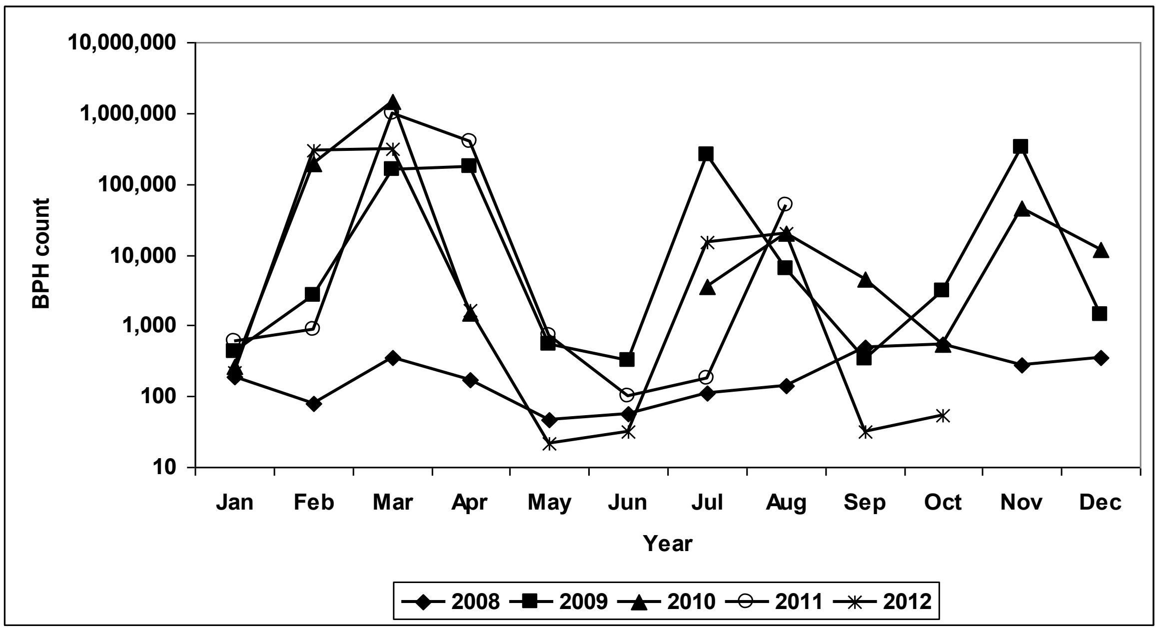
continuously losing an average of 1 million tons of paddy annually. In early 2012, the PRC's southwestern provinces lost about 10 million tons of rice due to heavy planthopper outbreaks. Rice planthopper outbreaks have also been reported, albeit at lower scales, in Bangladesh, Cambodia, India, Malaysia, Myanmar, and the Philippines. As these nations continue to face the same planthopper problem, the farm practices on dealing with pests were systematically observed to test whether planthopper outbreaks have been induced by insecticide misuse.

2.2 Insecticides and Pest Outbreaks

Planthoppers are typically r-strategists[2] that live and breed only in rice and are completely adapted to the rice ecosystem. They normally exist in rice fields in very low numbers of less than five planthoppers per plant and do not damage the rice plants or cause yield loss (Heong, Aquino, and Barrion 1992).

However, they can destroy crops in 2 weeks if their populations increase exponentially. The data from light traps (insect-recording devices to monitor planthopper adults and their migration patterns) from Chainat Province in Thailand indicate that this may have been the case as shown in Figure 1. The graph indicates the sudden increase of BPH populations from 2008 to 2012. In 2009, the BPH count in January was less than 1,000. The number surged to 100,000 in March. This was much higher than the BPH migration peak that was recorded in 2008, which was then 300.

Figure 1: Monthly Brown Planthopper Light Trap Catches in Chainat, Thailand



BPH = brown planthopper.

Note: X-axis = monthly totals of BPH Counts recorded in log scale, Y-axis = months of the year.
The cumulative BPH monthly total of the year showed that populations developed rapidly in the months of February to April, July to August, and in November.
Source: Data from Chainat Rice Research Center, Chainat, Thailand. Courtesy of Chairat Chanoo.

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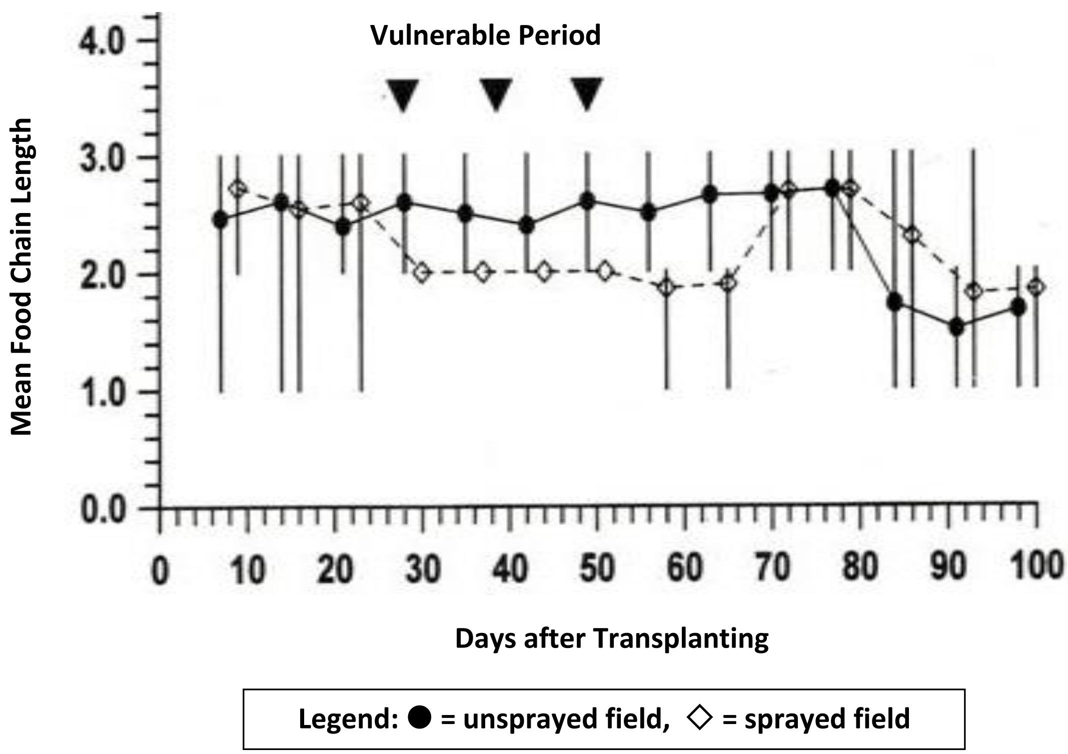
[2] r-strategists are organisms with high biotic potential that are able to rapidly colonize a habitat and utilize the resources. They tend to be small with short life cycles and are able to multiply quickly and often exploit unstable environments. Normally, their populations are constrained by natural forces such as biological control.

Under normal circumstances, the rice ecosystem has a rich biodiversity of arthropod predator and parasitoid species that provide pest regulation ecosystem services, which keep planthopper numbers at bay. It is when this rich biodiversity is destroyed that the planthopper population becomes out of control, growing exponentially into outbreak proportions.

Scientific studies (Way and Heong 1994; Bottrell and Schoenly 2012) have shown that planthopper outbreaks can be traced to the misuse of insecticides. Farmers in most Asian countries spray insecticide in the early crop stages (Heong and Escalada 1997). Early insecticide spraying has the effect of reducing the food chain length[3] from three links (rice–pests–enemies) to two links (rice–pests), rendering the crop vulnerable to the exponential growth of the invading planthoppers (Heong and Schoenly 1998). Figure 2 shows the differences in the mean food chain length between the unsprayed and sprayed fields. The vertical lines depict range in food chain length for sprayed and unsprayed food chains on each sampling date. On pre-spray days, food chains had up to three links (rice–pests–enemies). However, after the first deltamethrin spray on the 29th day after transplanting, the mean food chain length decreased from 2.6 to 2.0, which resulted in a web containing two-linked chains only (rice–pests).

In addition, the early sprays also disorganized the predator–prey links and made biological control functions ineffective. Settle et al. (1996) noted that insecticides reduced natural enemy populations, which resulted in resurgence of pest populations, particularly BPH, which is the "vulnerable period" as shown in Figure 2.

Figure 2: Impact of Insecticides on the Mean Food Chain Lengths in Rice Ecosystems



Source: Heong and Schoenly (1998).

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[3] Food chain length is the number of links (not species) of all maximal food chains from a basal species to a top predator.

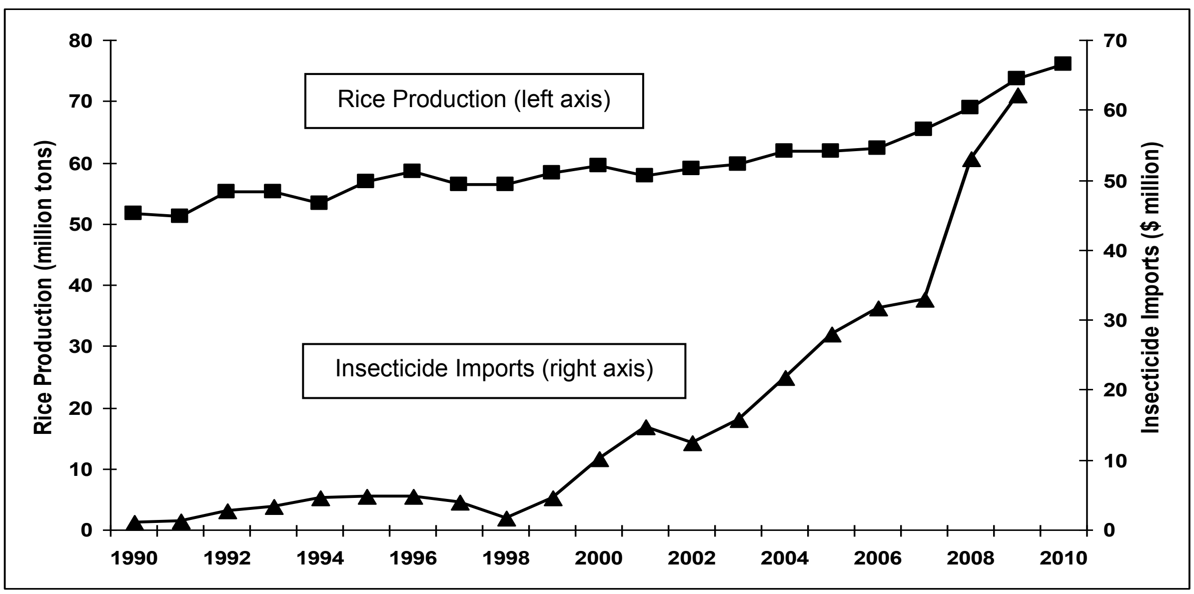
Insecticides, especially pyrethroids[4] and organophosphates,[5] have disproportionate killing effects on the predators and parasitoids, which are often smaller in size, are aquatic, have soft bodies, and move about in prey search. The spray equipment of Asian rice farmers is generally of low quality, resulting in more than 80% missing the pest targets and instead ending up in the water, thus destroying the natural predators. With the natural predators gone, insects flourish and increase in number unhampered.

3. Insecticide Marketing and Information Supply Chains

Scientists also showed that planthopper outbreaks are due to excessive insecticide use (Way and Heong 1994; Bottrell and Schoenly 2012). In most cases, the rice crop requires no insecticide use (FAOSTAT 2012) or just one application in the entire crop season (Heong and Schoenly 1998).

Insecticide imports of the member states of the Association of Southeast Asian Nations (ASEAN)[6] have been on a significant uptrend in the last 5 years. Figure 3 shows the dramatic rise in insecticide imports relative to the fairly stable growth in rice production in Indonesia in the last 20 years.

Figure 3: Rice Production and Insecticide Imports in Indonesia, 1990–2010



Source: Data from FAOSTAT (2012).

[4] Pyrethroids are a group of synthetic insecticides with chemical structures similar to natural pyrethrins produced by flowers of pyrethrums (*Chrysanthemum cinerariaefolium*). Most of these compounds are less toxic to mammals and less persistent in the environment as they are easily broken down by sunlight.

[5] Organophosphates are a group of organic insecticides that are generally esters of phosphoric acid. These compounds tend to have acute toxicity to mammals and are persistent in the environment.

[6] The Association of Southeast Asian Nations is composed of 10 member states: Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam.

In Southeast Asia, the sharp increase in imports and the use of insecticides can be attributed to the aggressive marketing strategies of agricultural insecticide companies, similar to those used in the promotion of fast-moving consumer goods. Insecticides being sold in this manner are not consistent with the principles of integrated pest management (IPM) and the International Code of Conduct on the Distribution and Use of Pesticide of the Food and Agriculture Organization of the United Nations (FAO).[7]

For instance, insecticide marketing is driven by attractive product packaging and brand names, while IPM requires knowledge-based choices and rational decision-making. Calendar-based applications are promoted by insecticide marketing, which appeal to farmers as less thought needs to go into it, whereas IPM requires a good understanding of the local environment and the ecosystems, the biological cycles of pests, the relations of natural enemies and ecosystems, and their services in pest control. IPM promotes scientific rationality based on technical knowledge of ecosystems when deciding on insecticide use; insecticide marketing strategies focus on mass-scale consumer use to maximize returns.

The International Code of Conduct on the Distribution and Use of Pesticide is a voluntary code of conduct in support of food security, and protection of human health and the environment. It was developed by FAO and endorsed by 191 United Nations member states, the pesticide industry, trade unions, and nongovernment organizations (NGOs). Article 11.2 is commonly violated.[8] For instance, Article 11.2.18 states that "advertisements and promotional activities should not include inappropriate incentives or gifts to encourage the purchase of insecticides." However, in Indonesia and Thailand, raffle tickets, free vacations, and electric household appliances are offered to promote the sale of insecticides.

At a workshop sponsored by the Asian Development Bank, FAO, and the International Rice Research Institute in May 2011 involving eight ASEAN member states, it was confirmed that insecticides, which are toxic to humans when not used properly, are sold as fast-moving consumer goods in most of the ASEAN countries, except in Malaysia. Most insecticides are neurotoxins that can cause irreversible impairment of the human nervous system. They also contribute to chronic neurodegenerative disorders such as Parkinson's disease (Costa et al. 2008) and Alzheimer's disease (Casida and Durkin 2013), as well as autism, attention deficit hyperactivity disorder (ADHD), and low IQ in children through prenatal exposures (Bouchard et al. 2010). Since insecticides are nonspecific, they are also toxic to non-target species such as birds, amphibians, fish, and arthropods. In sharp contrast, in developed countries, insecticide sales and marketing are regulated, including the control of advertisements and promotional schemes.

To better understand excessive insecticide use and misuse, a study was conducted on insecticides and insecticide information supply chains in Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam. The study examined the flow of both insecticides and insecticide information, such as advice to farmers, to effectively control pests. This was augmented by a farm-level survey to track and quantify farmers' practices with respect to insecticide (mis)use and (mis)information.

The study found that 50%–99% of insecticides in these countries were supplied by rural retailers, who sell insecticide along with food, clothing, and other general merchandise. The retailers in these small convenience stores also act as extension workers who provide the farmers advice on

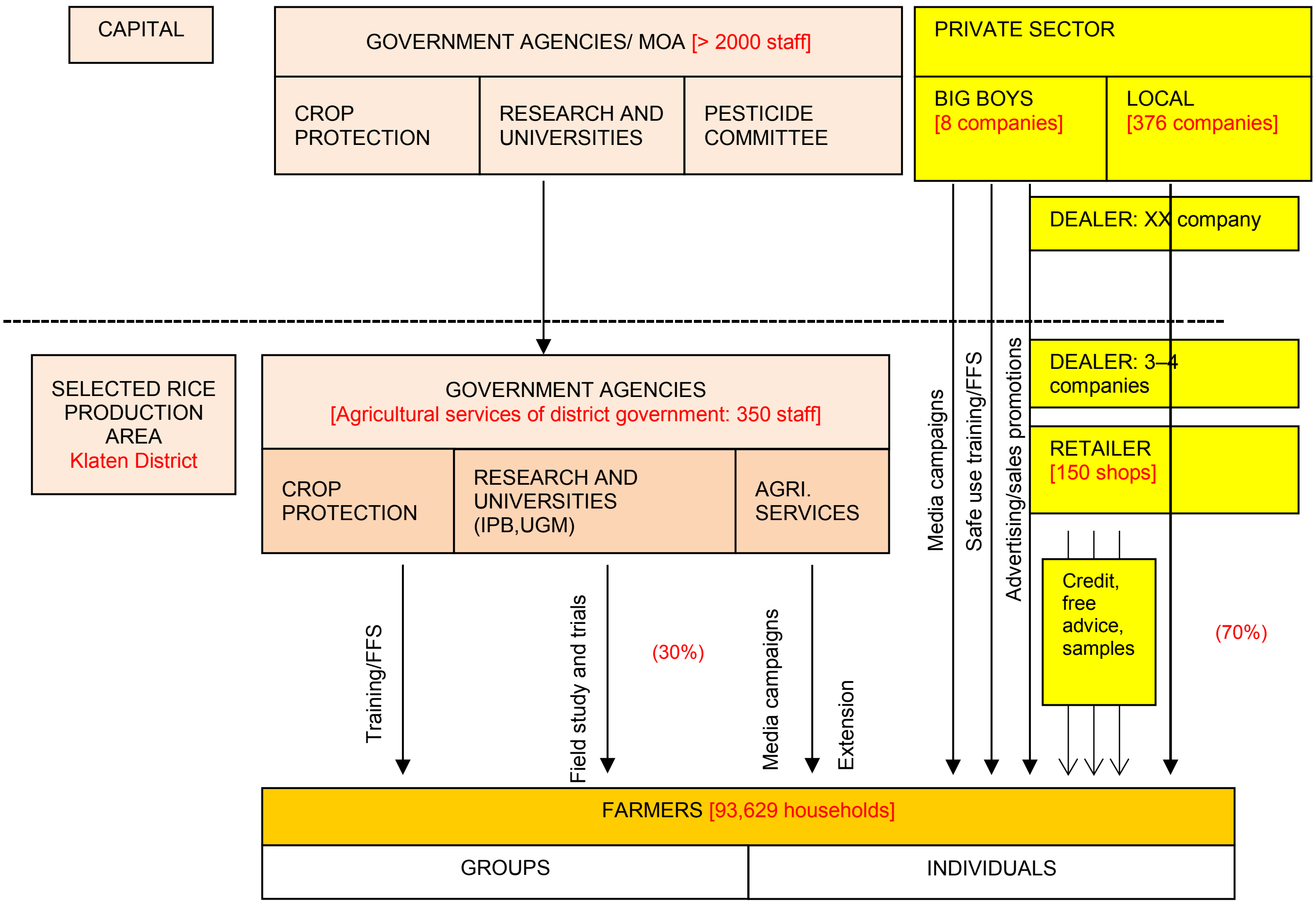
[7] See http://www.fao.org/docrep/005/Y4544E/y4544e00.htm.
[8] Article 11 is about pesticide advertising and Article 11.1 outlines the government's role in establishing pesticide marketing regulations, while Article 11.2 outlines what the pesticide industry should ensure.

appropriate dosage. This practice, coupled with the adoption of the sales and marketing strategies akin to fast-moving consumer goods, constituted the ”push” side of insecticide promotion. Sales schemes to entice farmers to buy insecticide included cash rewards, lottery tickets, bonus points, free holiday trips and trips to Mecca, free gifts, credit schemes, and multilevel marketing.

Mapping of the insecticide information supply chain showed that between 20% and 80% of the farmers in the eight ASEAN member states surveyed relied on the local insecticide dealers for pest management information, advice, and insecticide recommendations. This overt reliance on dealers or the dominance of dealers, coupled with the latter’s common recommendations of calendar sprays and use of insecticide “cocktails,” constituted the “pull” side of insecticide promotion. Figure 4 shows the insecticide information supply chain in Indonesia, wherein 70% of the insecticide information comes from insecticide companies and resellers. Both the government and private sector conduct their own farmer field schools, training, and media campaigns; however, the private sector appears to have more influence on farmers not only because retailers outnumber agriculture extension workers but also because they provide farmers with credit and incentives.

There is also evidence that some government workers are earning extra cash from chemical companies by promoting the use of their insecticides. For instance, agricultural extension agents in the PRC generate most of their salaries and office operating costs through pesticide sales (Hamburger 2002). In Viet Nam, extension staff often earn extra money by selling inputs to farmers and thus tend to bias the information they provide (McCann 2005). The interplay of all these factors in an environment of inadequate regulation and poor enforcement has invariably led to the perpetuation and escalation of insecticide overuse and misuse.

Figure 4: Rice Insecticide Information Supply Chain in Indonesia



FFS = farmer field school, IPB = Institut Pertanian Bogor (Bogor Agricultural University), MOA = Ministry of Agriculture, UGM = Universitas Gadjah Mada (Gadjah Mada University).
Source: Authors.

4. Insecticide Application and Productivity Gains

Economists have suggested that there are little or negative productivity gains from insecticide applications in rice production (Herdt, Castillo, and Jayasuriya 1984; Pingali, Hossain, and Gerpacio 1997). Since the spray equipment of farmers in Asia is generally inefficient and applications are made based on lack of appropriate information and knowledge, most insecticide applications are misuses. Misuse is defined as improper or incorrect use. Thus, when an insecticide is used for the wrong target pest or at the wrong time, or both, it is considered misuse. A study on farmers' insecticide use was conducted in Leyte, Philippines, and results showed that more than 80% of the sprays applied were considered misuse. Among the 300 farmers interviewed, 78% started spraying insecticides in the first 30 days after transplanting. As for the sprays used, only 19% of the 841 sprays had chemicals intended to prevent pests and yield loss (Heong, Escalada, and Lazaro 1994).

Regression analyses of correlating yields and insecticide sprays from eight surveys of 5,410 farmers in the Mekong Delta in Viet Nam revealed that the regression was not significant (meaning no relation) in five cases, negative and significant (implying high yield with less use of insecticides) in two cases, and there was only one case with a positive correlation, with a coefficient of 0.123 (Table 1).

When input and labor costs were considered, productivity gains were negligible (Pingali, Hossain, and Gerpacio 1997). Economists have also argued that when externalities such as health and environment costs are considered, insecticide applications often outweigh the limited productivity gains (Herdt, Castillo, and Jayasuriya 1984; Antle and Pingali 1994; Pingali, Hossain, and Gerpacio 1997).

Table 1: Regression Analyses of Yield–Insecticide Applications of Farmers in the Mekong Delta, Viet Nam

Area/Year	F value	Probability	Significance	Regression coefficient
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

Source: Data from Escalada et al. (2009).

5. Conclusions

5.1 Insecticides Marketed as Fast-Moving Consumer Goods

In summary, most insecticide sprays that farmers apply in rice crops are unnecessary. Hence, insecticide misuse is the main reason planthopper outbreaks continue to spread across the ASEAN region. Aggressive marketing of insecticides without commensurate proper advisory services exacerbate the situation. As shown in Figure 4, pest management advice and information is mainly supplied by the private sector, which promotes their own products in their extension work. A study in Thailand also showed that pesticide retailers are often the only or main source of pesticide recommendations and information (Jungbluth 1996).

These outbreaks have caused huge losses not only in monetary terms of production but also, in extreme cases, in the lives of farmers. Farmers continue to become the victims of the marketing strategy to entice insecticide buying and usage. As shown by research, rice ecosystems, when left undisturbed by unnecessary insecticide sprays, can regulate themselves and rice can grow to full harvest without the occurrence of planthopper outbreaks. The adoption of such sustainable techniques does not require a lot of resources. In fact, it saves farmers from incurring huge debts and losses.

In recent years, spending in the agriculture sector in most Asian countries has declined. Lowder and Carisma (2011) noted that expenditures on agriculture as a share of total public expenditure decreased in all regions except Europe and Central Asia from 1980 to 2007. The 2010 data from the International Food Policy Research Institute showed that Indonesia's agricultural spending dropped from 10% to 3%. Among the agricultural expenditures, investment on agricultural extension services has been most affected. On the other hand, the insecticide industry has strengthened its marketing networks, penetrating into local villages.

Cognizant of the extent of insecticide misuse and misinformation, there is a need to prioritize the strengthening of insecticide marketing regulations and enforcement as well as to regulate insecticide information through structured certification programs for retailers, dealers, and plant protection service providers. The dangers of insecticide misuse and misinformation should also be mainstreamed, especially into the consciousness of farmers, to ensure the sustainable development of Asian rice farming and food security and to restore ecological resilience. There is also a need to develop an analytical framework incorporating supply chain and full-cost accounting to better understand and present the socioeconomic impact of planthopper outbreaks, especially toward enhancing policy discussions.

Plant protection services in Asia have been designed like a fire brigade service to hunt and kill pests. The Millennium Ecosystem Assessment (2005), on the other hand, clearly demonstrates the value of ecosystem services and their conservation for sustainable pest management. To build ecosystem services, structural transformation and professionalization of plant protection services are needed. These should include information databases, diagnostics, and accreditation programs to correct insecticide misuse and to generate informed and well-balanced recommendations for farmers. There is also a need to implement a policy requiring insecticide sellers to be certified and licensed, similar to doctors and pharmacists who prescribe and sell medicine. In that way, farmers can be assured that they receive the proper information on insecticide use.

5.2 Ecological Engineering as an Enabler to Fix Insecticide Misuse

In parallel with policy and structural reforms in plant protection services, the ecological engineering approach can be usefully employed to build ecosystem services. This approach involves three ecological strategies to improve pest suppression (Gurr et al. 2012). The first is to reduce mortality of beneficial arthropods by reducing insecticide use, especially in the early crop stages. The second is to provide alternative food sources in some arthropod species for the predators in the early crop stages. Avoiding early-season insecticide use in the first 40 days after sowing will also enhance this second strategy. The third is to enhance hymenopteran parasitoids by habitat manipulation like growing nectar-rich flowering plants on the bunds. A huge diversity of pest parasitoids can benefit from the bund flowers as they provide nectar for food (Gurr et al. 2011). Egg parasitoids of planthoppers, for instance, increase their attack capacities when they feed on sesame flowers (Zhu et al. 2013). Thus, there is a huge potential to adopt ecological engineering and reduce insecticides to conserve biodiversity and ecosystem services for sustainable pest management in rice production. In addition, growing flowers on bunds can also be a communication tool to motivate farmers to reduce insecticides despite the strong insecticide marketing and advertising influences (Escalada and Heong 2012). Pest-tolerant varieties developed through traditional breeding or biotechnology grown under ecologically sustainable environments will also be more durable (Gallagher, Kenmore, and Sogawa 1994).

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Addressing Planthopper Threats to Asian Rice Farming and Food Security: Fixing Insecticide Misuse

Planthopper outbreaks in rice production are induced by insecticides that destroy natural control mechanisms. In Asia, excessive insecticide use is fueled by marketing promotions in the manner of fast-moving consumer goods in poorly regulated markets. Unknowingly, farmers and consumers are also exposed to health risks posed by insecticides, which include Alzheimer's and Parkinson's disease. Field research has also shown that there is little or no productivity gain for farmers' insecticide use. Instead, they increase crop vulnerability to planthopper outbreaks.

The paper discusses the threats of rampant insecticide misuse in Asia and emphasizes the urgent need to reform plant protection services and pesticide marketing regulations. Ecological engineering methods to increase ecosystem services and reduce insecticide use may be introduced to increase ecosystem services and promote sustainable production systems and food security.

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Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
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Publication Stock No. WPS135985-3

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