RICE PLANT HOPPER OUTBREAKS: A MAN-MADE PLAGUE?

1.0 INTRODUCTION

In the year 2005, outbreaks of rice plant hoppers, a serious pest of rice, ravaged rice plants in Vietnam and China. The outbreak threatened rice yields and farmers' livelihoods in both countries. This resulted in both countries allocating funds for chemical insecticides to control the pests. The irony of this response is that similar outbreaks in the 1970's and concomitant scientific studies showed that rice plant hopper (RPH) outbreaks, particularly of the rice brown plant hopper (BPH), were in fact *caused* by regular use of chemical insecticides. Indeed, past experience in Asia had shown that removing insecticides from rice cultivation helped conserve the natural enemies of rice pests, which in turn prevented RPH outbreaks. That governments and rice farmers returned to using chemical insecticides suggests that the lessons learned over 30 years ago had been forgotten.

Hence, the primary purpose of this fact sheet is to remind policy-makers, scientists, extension workers, economists, social workers and farmers about the causes of RPH outbreaks. It includes measures to help farmers understand the rich biodiversity existing in rice fields, and how to harness this biodiversity for more successful rice cultivation without the use of synthetic/chemical inputs. This approach, known as *biodiversity-based ecological agriculture* (BEA), leads to greater profitability for farmers, mitigates global warming and protects the agro-ecosystem. For this fact sheet, a BEA approach may be defined as one that promotes an understanding of the role of natural enemies known to keep insect pests in check and to enhance the presence of these natural enemies to avoid outbreaks, rather than relying on chemical insecticides.

Section 2 explains the biology of the three most common RPH species in Asia. The ways RPHs damage rice plants are described in Section 3. Section 4 addresses RPH outbreaks in Asia. In Section 5, both short and long-term actions to understand and prevent outbreaks of the RPH are provided, together with success stories of RPH management.

2.0 THE RICE PLANT HOPPER

2.1 Brief History of RPH in Asia

Rice plant hoppers are insects known to be serious pests of rice in temperate countries such as Japan (Dyck and Thomas, 1979) and Korea (Paik, 1977). However, until the 1970s, they were not considered a serious threat in tropical Asia. Two species of RPHs had been reported as secondary pests of rice prior to 1970: *Nilaparvata lugens* (Stål) and *Sogatella furcifera* (Horvath). However, this changed in the 1970s when RPHs suddenly emerged as significant pests of rice with serious outbreaks in tropical countries, where they had before existed for millennia as minor herbivores which mainly served the role of feeding their predators. These outbreaks were exacerbated by viral diseases associated with the hoppers.

In particular, the BPH came to be considered as the worst pest of rice, causing much distress among rice growers in the tropics and threatening to undermine national food security, as rice is the staple food of Asia. National and international research organizations addressed this new challenge by organizing two major symposia about an insect that had been previously only a minor pest (Kalshoven, 1988, Yunus and Balasubramaniam 1975). The first symposium was held in Bali in 1977. Then in 1979, the International Rice Research Institute (IRRI) organized the international symposium "Brown Planthopper: Threat to Rice Production in Asia". These two symposia heralded a surge in the study of RPHs in major research journals.

The sudden emergence of RPHs as major pests of rice has been linked to the advance of the Green Revolution in countries such as Bangladesh, Brunei, China, Fiji, Korea, Malaysia, Papua New Guinea, Philippines, Solomon Islands, Sri Lanka, Thailand and Vietnam (Heinrichs, 1977; Dyck and Thomas, 1979). The large outbreaks of this pest in Indonesia (Mochida, 1979), Philippines (Mochida et al., 1977) and Malaysia (Lim et al., 1978) posed great challenges to rice farmers in Asia.

In Japan, outbreaks of tropical RPHs (such as the BPH) occurred which appear to have originated in tropical Asia (Kisimoto, 1971). The arrival of these plant hoppers were often monitored using large swing nets in June and July of each year. These were followed by extensive spraying of the rice fields when migration was detected. Unsurprisingly, hoppers in Japan began to develop insecticide resistance.

While it was generally accepted that outbreaks of the plant hoppers in tropical Asia were insecticide-induced (Heinrichs et al, 1984), it was Kenmore et al. (1984) who pointed out the important role of existing natural enemies. He found that the use of chemical insecticides in rice fields killed these natural enemies, allowing RPHs to flourish. Based on this understanding, an Asia-wide programme was implemented by the Food and Agriculture Organization (FAO) of the United Nations for an Integrated Pest Management (IPM) approach to reducing the use of these insecticides in Asian rice fields. This programme resulted in successes in several countries in the region in reducing RPH outbreaks through the reduction of chemical insecticide use. For instance, when Indonesia cut production and subsidies for chemical insecticides in the 1980s, RPH outbreaks soon declined (Soejitno, 1999; Pontius et al. 2002).

However, recent outbreaks of the RPHs in China and Vietnam as well as Bangladesh, Malaysia, and Myanmar have coincided with the termination of the FAO programme. As noted in the introduction, it appears that the lessons learned in the past have been forgotten, and that there is a need to constantly remind governments about the causes of RPH outbreaks in Asia and the Pacific and the benefits that can be gleaned from a biodiversity-based ecological agriculture (BEA) approach.

2.2 The Insects

Class: Insecta
Order: Hemiptera
Family: Delphacidae

Three species of the RPH are known to farmers and scientists. However, only two are common to the tropics: *Nilaparvata lugens* (Stål) or the brown plant hopper (BPH) and *Sogatella furcifera* (Horvath) or the white-backed plant hopper (WBPH). Of lesser importance in the tropics is the smaller brown plant hopper (SBPH), *Laodelphax striatellus* (Fallén). It is often associated with rice plants in temperate climates.

2.3 Brown Plant Hopper

Prior to the 1970s, the rice BPH was little known in tropical Asia, although it is native to this region. This insect develops almost exclusively on rice plants and adults measure no more than 5 mm in size. The small size of this insect contributes towards its destructiveness. Many Malaysian rice farmers affected by BPH were initially skeptical when informed that the destruction of their crops was due to such a small insect.

Small outbreaks were reported in Malaysia, such as in Malacca in 1939, and patches of damage caused by the BPH were reported from 1957 to 1968. From 1974, small rice patches of less than 2 ha were reported to be damaged by the BPH in the northern states of Peninsular Malaysia until 1977 when 1,620 ha of rice land in the Tanjung Karang Irrigation Scheme, Selangor were damaged (see Figure 1).

Figure 1: Hopper burn caused by the brown plant hopper in the Tanjung Karang Irrigation Scheme, Malaysia (1977) (Photo by PAC Ooi)

2.3.1 Biology

Like many insects in the same family, the adults can exist in two physical forms, long-winged (also known as macropterous) and short-winged (also known as brachypterous). The long-winged adult BPH invades rice fields from surrounding fields, and if the field has few natural predators, the BPH will multiply and develop into short-winged forms that focus on producing big populations of hoppers, often found at the base of the rice plants near the water surface.

Figure 2: Long-winged *Nilaparvata lugens* Stål adults invade the field from neighbouring rice fields (Photo by PAC Ooi).

Figure 3: Short-winged *Nilaparvata lugens* Stål adult which appears after the initial invasion of the long-winged adults into rice fields (Photo by PAC Ooi)

The eggs of the BPH, laid inside rice stems (Figure 4), take about seven days to develop into nymphs (immature BPH). The nymph resembles its parent, except that it is smaller and lacks wings. There are five nymphal stages, which are completed in about two weeks. As insects possess only external skeletons, at each nymphal stage, there is a need to change the skin, a process called moulting (Ooi, 1992).

Figure 4: Eggs of the rice brown plant hopper (Photo by PAC Ooi)

Upon finding a suitable rice plant, the female BPH can lay up to 715 eggs in its lifetime. The eggs hatch into nymphs (Figure 5) and together with the adults, feed on the rice plants until they dry up.

Figure 5: Nymphs of *Nilaparvata lugens* Stål are usually found at the base of rice plants, near the surface of the water (Photo by PAC Ooi).

2.3.2 Natural enemies of BPH

A rich variety of parasitoids, predators and pathogens have kept BPH populations at low levels for as long as rice has been cultivated (van Vreden and Ahmadzabidi, 1986; Ooi, 1988). The most common and effective of these are spiders, especially the hunting spider, *Lycosa pseudoannulata* (Figure 6). Another important egg-feeding predator is the mirid bug, *Cyrtorhinus lividipennis* Reuter (Figure 7). Ooi (1988) suggested that in natural circumstances (i.e. without the use of pesticides), populations of these predators, especially *C. lividipennis*, increase with increasing populations of the BPH (Figure 8), enabling the predators to keep the BPH population under control.

Figure 6: Hunting spider with BPH as prey (Photo by PAC Ooi)

Figure 7: Mirid bug (Photo by PAC Ooi)

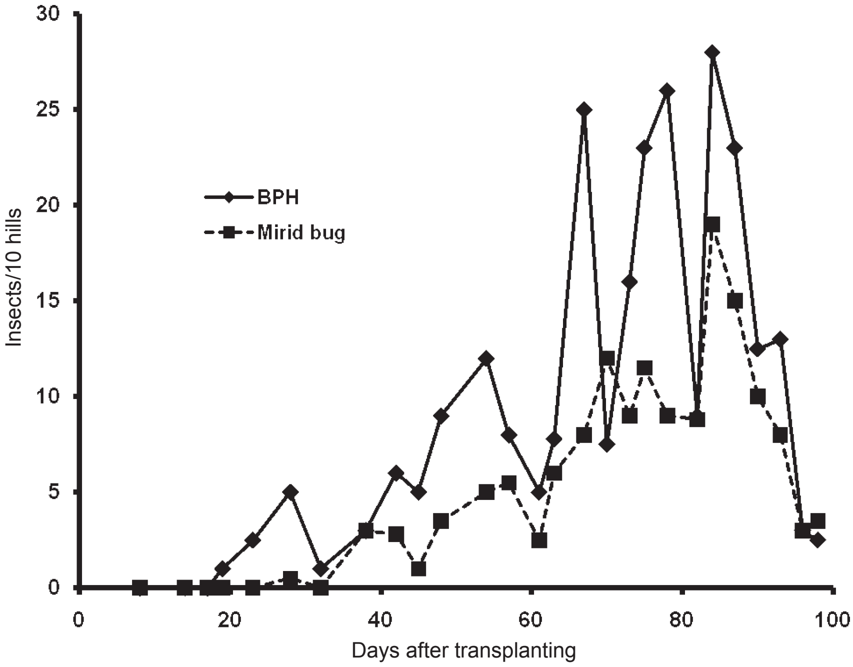

Figure 8: Comparison of populations of the brown plant hopper and its mirid predator in a field in Sungai Burong, Tanjung Karang Irrigation Scheme in season 1984/1, based on a sticky board sampling of 10 hills. As the BPH population increased, the population of the mirid predator followed suit and overwhelmed the pest population (based on data reported by Ooi, 1988b).

2.4 White-Backed Plant Hopper (WBPH)

Outbreaks of the white-backed plant hopper, *Sogatella furcifera* (Horvath) (Figures 9 and 10) are not as frequent as that of BPH. Indeed, the outbreak in 1979 in the Muda Irrigation Scheme in Kedah, Malaysia and its subsequent management is recorded in a report by Ooi *et al*. (1980). There was a limited intervention by the authorities who initiated some spraying of freshly damaged plants. More importantly, the farmers were taught about the role of insecticides in causing pest outbreaks due to destruction of the biodiversity existing in the rice fields. They were made aware as to how natural enemies kept the hopper in check. With support from the Muda Irrigation Authority, no further prophylactic use of insecticides was initiated and no more outbreaks were recorded. Only short-winged females have been reported (Figure 11). The populations of the WBPH are kept in check by natural enemies. The biology is similar to that of the BPH. This insect has not been reported to transmit any rice viral disease.

Figure 10: Hopper burn caused by the white-backed plant hopper in the Muda Irrigation Scheme, Malaysia (1979) (Photo by PAC Ooi)

Figure 11: Short-winged female WBPH (Photo by PAC Ooi)

2.5 Smaller Brown Plant Hopper (SBPH)

The smaller brown plant hopper, *Laodelphax striatellus* (Fallén) (Figure 12), is more abundant in the temperate and sub-tropical parts of Asia. It does not pose the same level of threat as the BPH. However, it is known to be a vector of the black streaked dwarf virus and the stripped virus, both of which infect rice plants. Like the BPH, it may exist in two morphological forms and its biology is similar too.

Figure 9: The white-backed plant hopper adult (long-winged form) (Photo by PAC Ooi)

Figure 12: The smaller brown plant hopper adult (long-winged form) (Photo by Mr. Jiang Xuehui of PPS Zhejiang, PR China)

3.0 DAMAGE TO RICE PLANTS BY THE RICE PLANT HOPPER

RPHs damage rice plants in two ways. First, **hopper burn** (Figures 1 and 10) occurs when large numbers of hoppers cause rice plants to dry up by sucking out the plants' fluids. Second, the BPH transmits **viral diseases** called rice ragged stunt (Figure 13) and rice grassy stunt. The smaller BPH is also known to transmit black streaked dwarf and stripe viruses in temperate rice fields. The damage caused by the RPH can be very extensive; for example, Mochida (1979) suggested a total loss of up to 5.3% of an overall 7.3 million hectares of rice in Indonesia in 1977. In a specific case, 100% losses due to hopper burn have been reported (Soejitno, 1999).

The conspicuous damage to rice plants from hopper burn can be very politically sensitive as well. Farmers who have lost their harvests may seek compensation from their governments, using graphic images of their crop losses and their families' resulting hunger to make their case.

As mentioned above, in addition to hopper burn, rice plants may suffer from two viral infections transmitted by the BPH, rice grassy stunt and ragged stunt. However, a survey by Ooi (1980) suggested that rice ragged stunt (RRS) occurs at a low level, as only 19.5% of 8560 fields had rice hills with signs of RRS. Only 0.2% of these infected fields had 5 or more infected hills. However, as the virus infections are transmitted by the BPH, a lower population of this hopper would result in a lower incidence of these viral diseases and less damage to rice plants (Ooi 1980). Stunted plants do not produce viable grains and could be considered as total loss to the farmers concerned.

4.0 RPH OUTBREAKS IN THE REGION

4.1 Major Outbreaks and Outcomes

The recent RPH outbreaks in the region have caused panic and fear of another price hike in Asia's essential staple crop. In China, the reported area of infestation by RPHs (especially the BPH) varied from about 18% in 2001 to about 51% in 2007 (Figure 14). What is more discouraging is an even higher usage of chemical insecticides, through promotion of fears

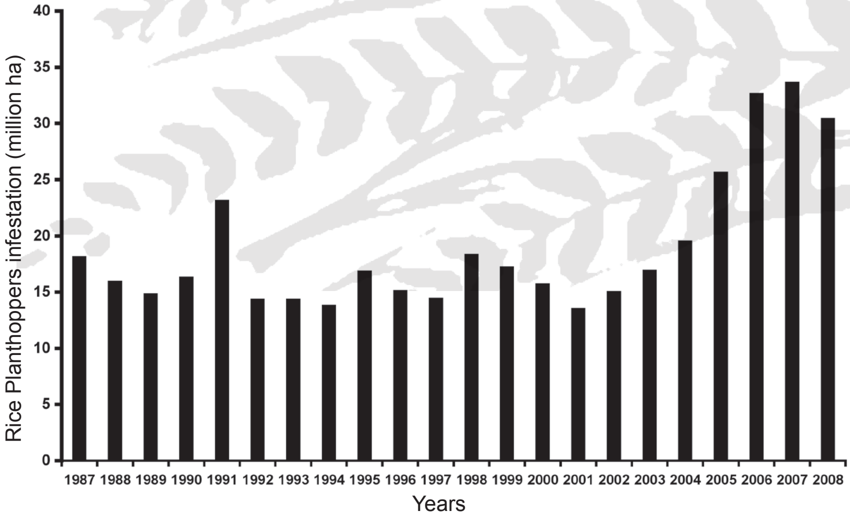

Figure 13: Rice ragged stunt symptoms on infected rice plants (Photo by PAC Ooi)

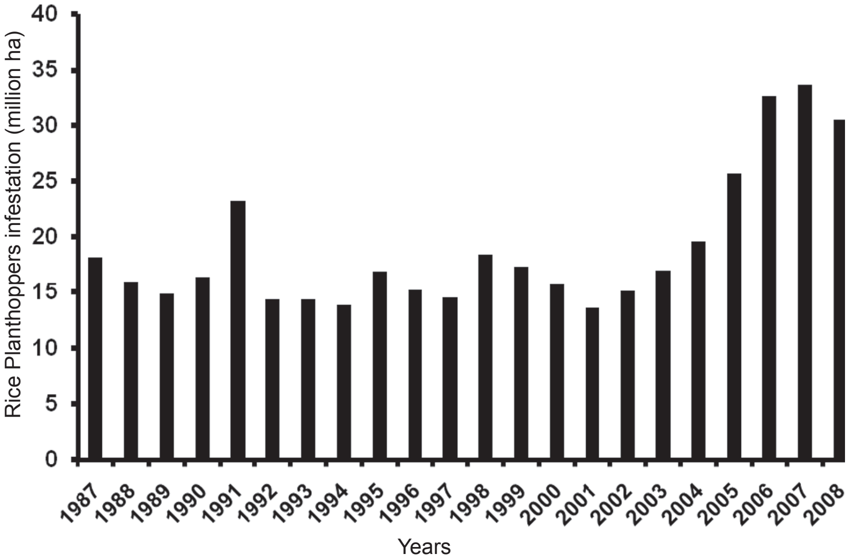

Figure 14: Areas infested by RPHs in China (1987-2008). Areas infested by RPHs appear to vary year to year but the trend is towards an increase in the late 2000s. (Source: Guo, 2009)

among the rice growers from agricultural extension workers.

In Vietnam, much emphasis was placed on farmer education and campaigns to reduce insecticide usage in rice fields after the outbreaks in 1978. However, a resurgence of hopper outbreaks was reported after 1990. Although there was a mandate to farmers not to spray within the first 40 days of cultivation, this was not effective as some farmers would ignore this ruling and spray anyway, thus perpetuating the RPH attacks. This in turn became grounds to justify further spraying. Figure 15 shows that the levels of hopper incidence increased after 1990.

There were calls by ecologists for farmer education in the natural biological control of BPH. These recommendations were made based on the successes reported by Pontius *et al.* (2002) although the evidence of such trainings were not monitored as the FAO programme had terminated.

In addition to the RPH outbreaks in China and Vietnam, in January and February 2010, news sources reported outbreaks of 133,300 ha in Thailand and 600 ha in Peninsular Malaysia. As in China and Vietnam, the immediate response in both countries has been to provide more insecticides to farmers. As we have seen, this approach is illogical because the plants cannot be saved and the insecticides will in fact cause more outbreaks.

4.2 Common Features and Contributing Factors

A study by Kenmore *et al*. (1984) on IRRI's fields in the Philippines described the common features of RPH outbreaks. It showed that outbreaks of BPH were associated with the absence of natural enemies such as the hunting spider. Figure 16, from Kenmore's study, clearly reveals the adverse impact of chemical pesticides. A field treated with insecticide had far more BPH after 85 days than an untreated field. In an untreated field, more predators survived to keep the hopper population in check.

This relationship of RPH outbreaks to insecticide use also appears to be reflected in the outbreaks in Indonesia associated with insecticide production with concomitant subsidies to rice farmers and the subsequent removal of insecticide subsidies. As shown in Figures 17 and 18, insecticide production in Indonesia fell sharply after the termination of subsidies in 1988. The production of milled rice, however, was completely unaffected by the drop in insecticide production. Indeed, rice production continued to rise steadily after 1988.

Similarly, in Thailand, increases in insecticide use during the years 1976-79 and 1984-90 were followed by new RPH outbreaks (Figure 19). This strongly suggests again the association between insecticide use and RPH outbreaks, showing that these are indeed man-made plagues.

5.0 BIODIVERSITY-BASED ECOLOGICAL AGRICULTURE SOLUTIONS

5.1 Immediate Action in Response to Outbreaks

Upon hearing reports of hopper burn from rice farmers, scientists and extension specialists must first determine if the reports are true. They must ascertain the area damaged by the hoppers, the extent of the damage and indeed, the practices of the farmers that led to the outbreaks. Often farmers are seeking compensation to offset money owed to unscrupulous traders that advanced them the insecticides to spray on their crops. Poverty usually will not

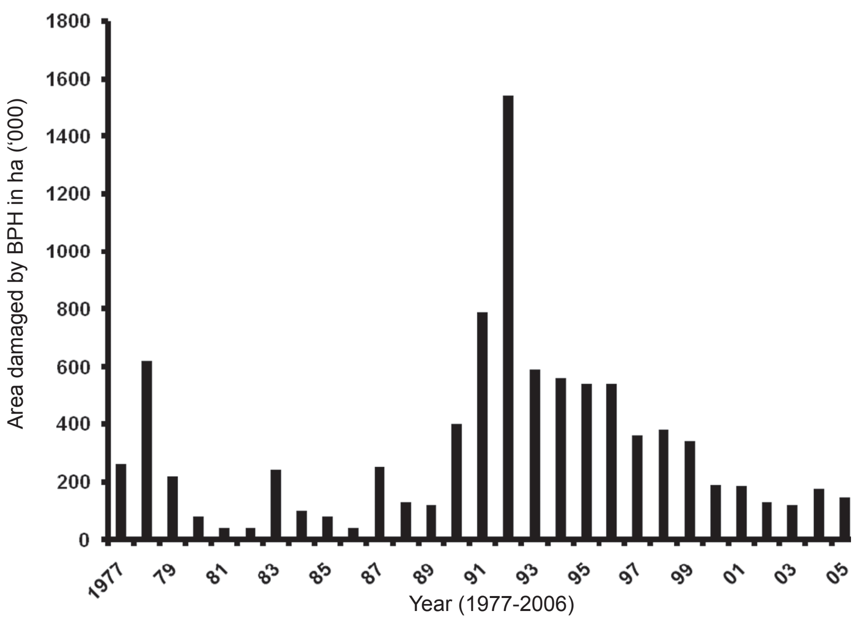

Figure 15: Rice growing areas in Vietnam infested by the brown plant hopper between 1977 and 2006 (Source: MARD, 2009)

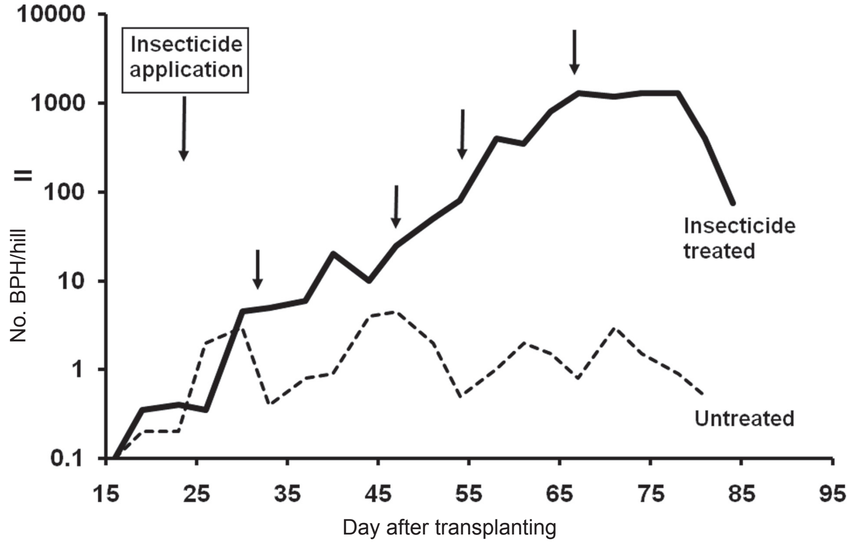

Figure 16: Density of brown plant hopper (nymphs + adults) on the IR20 variety untreated and treated with insecticides (diazinon at 0.75 kg a.i/ha was applied first followed by 3 sprays of decamethrin at 8 g a.i./ha) IRRI, 1979 season.

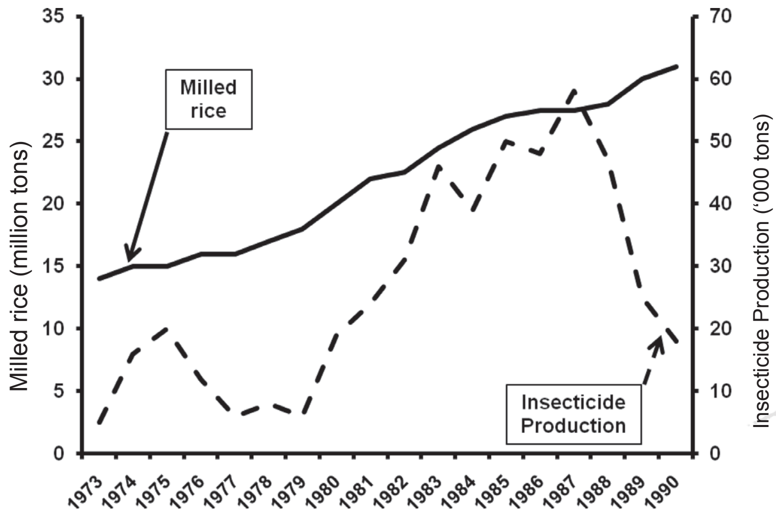

Figure 17: Insecticide and rice production in Indonesia (1973-1990) (modified from Soejitno, 1999). It is clear from this graph that the increase in rice production is independent of insecticide production.

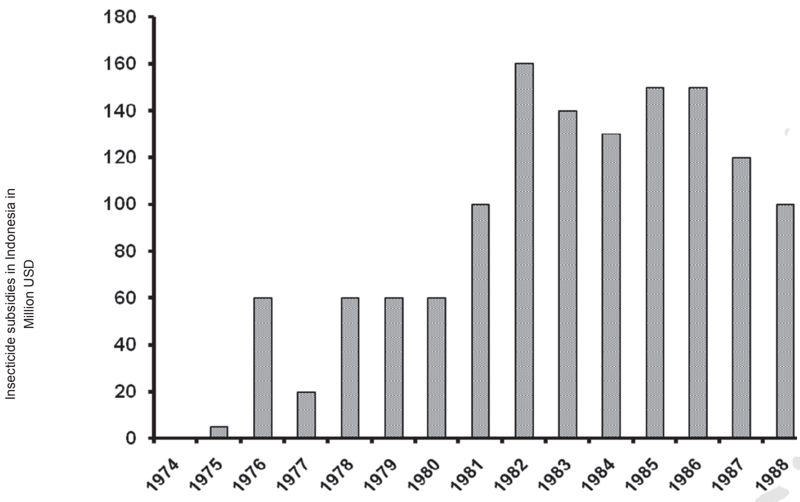

Figure 18: Insecticide subsidies in Indonesia (1973-1988) (modified from Soejitno, 1999). This graph shows the decline in subsidies for insecticide production in Indonesia.

enable farmers to invest in insecticides unless pushed to do so under threat of outbreaks of "holocaust" proportions. Equally important for the scientists and extension specialists is to determine the areas not affected and why. This will provide clues as to the causes of outbreaks and more importantly to avoid further outbreaks rather than exacerbating them.

Following a devastating rice hopper outbreak, farmers often need government support to acquire fresh planting material, especially new seed varieties. Farmers also expect government officials to explain why these outbreaks occur. Farmers need to be educated about dragonflies, damselflies, predatory spiders and the vast array of other insects that kill pests such as RPHs. Some efforts have been made through Farmer Field Schools to help farmers understand the role of natural enemies (Shepard *et al*., 1987; Ooi, 1988a) but such education needs to be widespread throughout the region in order to effectively control RPH outbreaks.

5.2 Long-term Solution: Farmer Education and Empowerment

The proper role of scientists and extension specialists is to understand the ecology of RPHs and advise both farmers and governments on long-term solutions. Whenever possible, they should support farmer-to-farmer education training programs to spread BEA strategies between farmers themselves. They must also advocate the provision of more support from the government for ecological agriculture approaches and reducing the reliance on chemical insecticides.

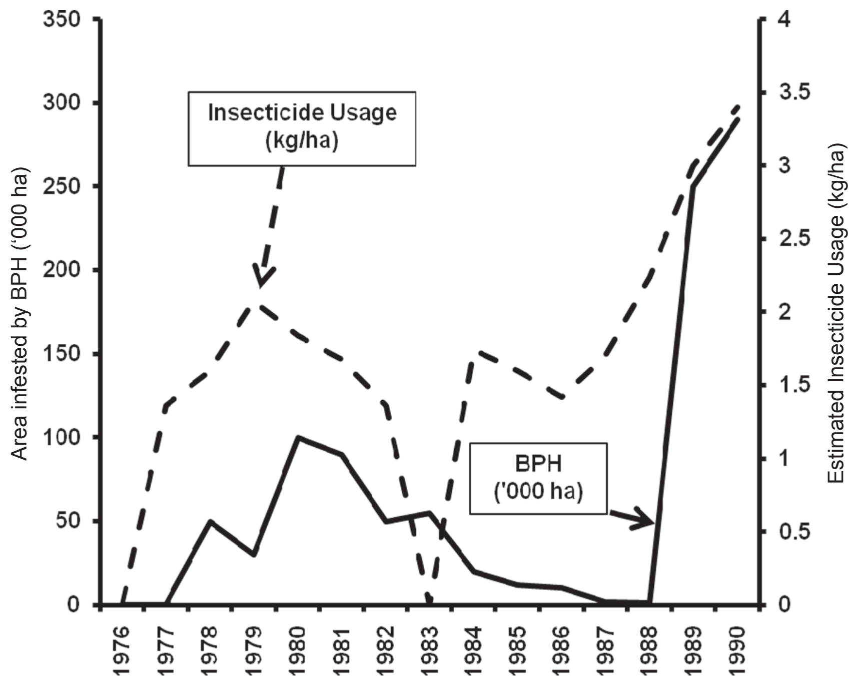

Figure 19: Thailand's BPH crisis. Insecticides were applied before the peaks of the BPH outbreaks (modified from presentation by Kenmore in "Rice Plant Hoppers: Old Problem, New Development" [2006])

5.2.1 Farmer Field Schools

The Farmer Field School (FFS) concept was introduced as part of the IPM programme of the FAO. Under this concept, in order to detect problems early, farmers must inspect their rice plants regularly (Figure 20). They should examine the rice plants both at the center of the field and at the sides, especially at the plant's base. Upon returning from the field, farmers, working in groups, will be able to do an agro-ecosystem analysis that will enable them to make decisions based on field observations and share their findings with other farmers (Figure 21).

Three basic experiments should be adopted to introduce farmers to biodiversity and its conservation. Often, this will require the training of facilitators to facilitate farmer learning.

Figure 20: Going into the rice field to determine plant conditions

Figure 21: Farmers doing an agro-ecosystem analysis after collecting data from the rice field. This analysis will help them make informed decisions. Note that farmers prefer pictorial and numerical presentations rather than words (Photo by PAC Ooi).

5.2.1.1 Insect zoos

The insect zoo was developed as part of the farmer field schools. As the name suggests, the insect zoo is about learning by using live insects and helps farmers to comprehend the biology and ecology of arthropods found in rice fields (Ooi *et al,* 1991). Often it consists of collecting insects and determining if they are pests or predators (Figures 22 and 23). Following this, the facilitator demonstrates the nature of the insect being studied, whether pest or predator (Figure 24). This approach fits Winarto's observation (2004) that the discovery process helps foster the farmer's own creativity, leading to better understanding and confidence. It is the first step towards understanding that not all arthropods in the rice fields are pests!

Figure 22: Collecting live arthropods (Source: Ooi *et al,* 1991)

Figure 23: Keeping arthropods with plant parts (Source: Ooi *et al,* 1991)

Figure 24: Demonstrating how biological control works to farmers (Source: Ooi *et al,* 1991)

5.2.1.2 Exclusion technique

In exclusion cage experiments (Figures 25 and 26), cages were initially cleaned of all arthropods (Figure 26). Pairs of BPH (one pair per hill) were introduced into the cage. After 24 hours, some cages were opened at the bottom to allow predators in while the BPH remained inside. One and half months later, populations of BPH had reached very high levels in cages where predators were kept out (closed cage) while populations of BPH remained low in cages where predators were present (cage opened) (Figures 27, 28 and 29). This simple experiment is one of the most effective ways to show that predators are important in keeping BPH populations low.

Figure 25: Preparing the cage (Source: Ooi *et al,* 1991)

Figure 26: Completing the cage with netting (Source: Ooi *et al,* 1991)

Figure 27: Cleaning the plants (Source: Ooi *et al,* 1991)

Figure 28: Showing results to farmers (Source: Ooi *et al,* 1991)

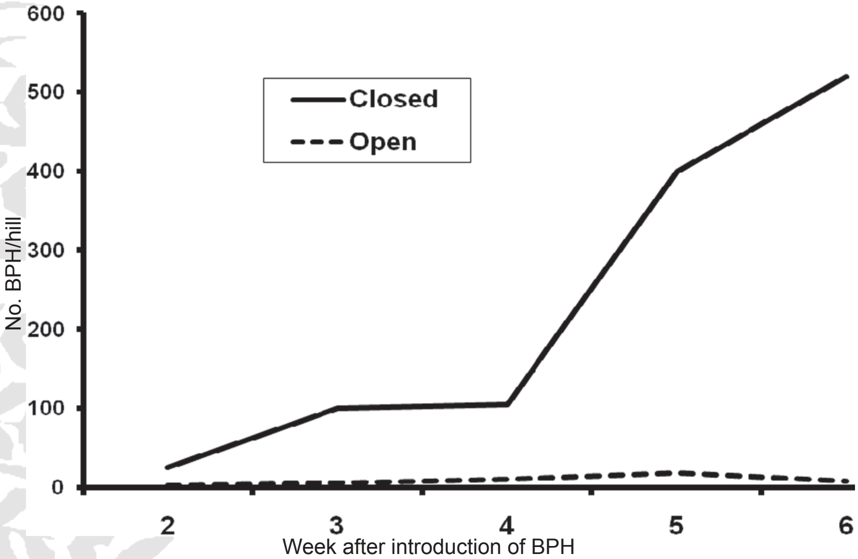

Figure 29: Populations of the brown plant hopper under two cage conditions—closed and opened cages—in Sekinchan, Malaysia in 1984, season 1. Note that in the absence of effective predators such as lycosid spiders, populations of BPH exploded into outbreak proportions. This is an effective way to demonstrate the role of predators in keeping pest populations in check (adapted from Ooi, 1988b).

5.2.1.3 Comparison studies

The disruption of natural control by insecticides may be observed by comparing fields with and without regular spraying of insecticides. In a study in Sekinchan, Selangor, Malaysia during the second season of 1983, a field that received only one spray had lower BPH populations than that of another field with regular sprays of endosulfan, trichlorfon, fenvalerate and 2-sec-butylphenyl methyl carbamate (BPMC). The higher values of BPH/predator ratios in regularly sprayed fields suggest that populations of predators were reduced with concomitant increase in hopper populations (Figure 30).

5.3 Nature as the Best Ally

Scientific research and farmers' own experience have firmly established that the best approach for managing rice hoppers is to work together with nature. Based on the long-term farmer education process, it is obvious that there is a need to familiarize farmers with the nature of natural biological control in the rice fields. The rich biodiversity of "friendly" arthropods in rice fields was determined by Settle *et al*. (1996) who showed clearly how the food chain of prey and predator was sustained in tropical rice cultivation. Hence, it is timely to bring this science to farmers. This will lead to enhanced evaluation of the impact of natural enemies in the rice ecosystem (Shepard and Ooi, 1992).

These natural enemies have been present since rice was farmed and continue to offer a more effective alternative to the use of chemical insecticides. The recent outbreaks highlight the need for effective farmer education programmes in all rice-growing countries in Asia and the Pacific, including farmer-to-farmer training and farmer field research. Invariably, this will result in less use of pesticides in the rice ecosystem. Quality farmer education will help farmers expand their knowledge base, increase their incomes and conserve precious ecosystems.

5.4 Lessons for the Future

The experiences of various Asian countries in dealing with RPH outbreaks in the past provide valuable lessons in addressing current RPH plagues. For instance, in Indonesia in the mid-1980s, a group of scientists convinced President Suharto of the importance of reducing the use of chemical insecticides in rice farming. This led to the

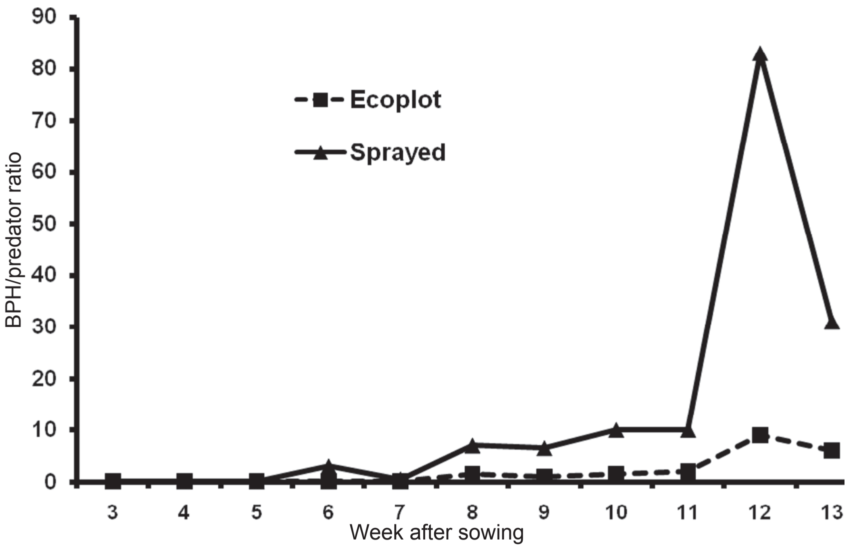

Figure 30: Comparative studies of sprayed and ecological rice plots in Sekinchan during season 83/2 using a sticky board to collect arthropods from 10 rice hills per sample

banning of 57 broad spectrum insecticides from rice fields, the 1986 Presidential Decree eliminating subsidies for insecticides, and the promotion of farmer education. These measures allowed Indonesia to achieve self-sufficiency in rice production and earned President Suharto the World Food Prize. Soejitno (1999) described Indonesia's successful approach as "operationalizing an ecological perspective in farm management".

Similarly, the government of President Ramos in the Philippines enacted a national policy of Integrated Pest Management with a focus on farmer education (Rola *et al.* 1998). In Malaysia, the success in conserving natural enemies is reflected in the reduction of RPH outbreaks (Ooi, 1996). However, it must be noted that these successes are offset in part by officials who continue to promote the unnecessary use of pesticides. Hence, there is a need to sustain the achievements of the early years of the FAO Rice IPM Programme.

Farmer field schools should be upgraded to Biodiversity-based Ecological Agriculture (BEA) Field Schools which promote BEA concepts and practices. In addition, there should be a concerted move towards participatory technology development, which involves empowering farmers to carry out their own adaptive research grounded on a firm understanding of the agro-ecosystem. This will greatly enhance the knowledge, skills, innovation and confidence of rice farmers who will then be better able to control pests and better positioned to profit from sustainable rice production.

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