

Situation of planthoppers in Asia

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The brown planthopper *Nilaparvata lugens* (Stål) and the whitebacked planthopper *Sogatella furcifera* (Horvath) are the two most important planthoppers in Asia. They cause plants to wilt, known as hopper burn. To know the current problems of planthoppers in Asia, questionnaires relating to the historical trends of distribution, damage to the rice crop, occurrence of insecticide resistance, management of planthoppers, and research activities from 1998 to 2007 were sent out to our Asian partners in China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam.

The results of the survey showed that the predominant management option of planthoppers in most countries today continues to rely solely on insecticides. Insecticide resistance to planthoppers was recorded in Thailand, China, and India. All our Asian partners focus more on insecticide evaluation research than on field resistance and ecology.

Planthoppers constitute a large group of phytophagous insects in the Order Hemiptera. Distributed worldwide, all members of this group are plant-feeders and some species are considered pests. In Asia, two planthoppers of economic importance are the brown planthopper (BPH), *Nilaparvata lugens* (Stål), and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath) of the Family Delphacidae. They damage plants directly by sucking the plant sap and by ovipositing in plant tissues, causing plant wilting or hopper burn. When conditions are unfavorable, especially when the crop is already dead, they migrate into a crop in large numbers. In China, both the brown planthopper and whitebacked planthopper migrate from the warmer, tropical regions of southern China to the Korean peninsula, as well as to Japan and central China, in the early summer of each year (Turner et al 1999). These regions are unable to sustain populations on the peninsula in the winter. The distance these migratory pests must travel is more than 1,000 km and much of it is over the ocean. It has been shown that favorable meteorological conditions of sustained strong southwest winds in the lower atmosphere, which are often associated with the “Bai” front, are necessary for successful migration. Simulation studies on migration suggest that the source region for early-season planthopper migrants to Korea is southeastern China

(south of 25°N and east of 115°E) (Zhu Min et al 2000). The results also indicate that planthoppers must have the ability to fly continuously for at least 30 and up to 48 hours, with much of the flight over the ocean, and that the altitude of flight may vary from 500 m to 1,500 m from one episode to another. If more remote source regions or circuitous migration routes are to be considered, much longer flight durations would have to be assumed in most cases.

Of the two planthoppers, the brown planthopper not only directly damages the rice crop but also transmits viral diseases of rice such as grassy stunt and ragged stunt (Reissig et al 1986). For many years, brown planthoppers have been a serious threat to rice production throughout Asia (IRRI 1979). In the 1970s, they caused extensive damage to the rice crop in Asia (Dyck and Thomas 1979). They were formerly only a minor pest in most tropical countries of Asia. Many regard the BPH as the number-one insect pest of rice in Asia today, primarily because of the unpredictability of the infestation and the dramatically severe damage it causes.

The whitebacked planthopper, though not a virus disease transmitter, occurs widely and can become sufficiently numerous to kill plants by hopper burn (Reissig et al 1986).

Shepard et al (1995) have shown that the populations of both the brown planthopper and whitebacked planthopper increase after insecticide applications. Because of widespread misuse of insecticides, outbreaks of BPH have occurred, thus killing natural enemies that normally play a key role in suppressing planthopper populations in rice (Kenmore et al 1984). Moreover, the promiscuous use of pesticides also promoted resurgence of the insect pest (Heinrichs and Mochida 1984). Likewise, it is believed that excessive use of urea as a nitrogenous fertilizer can also lead to outbreaks by increasing the fecundity of BPH (Preap et al 2002).

To learn more about planthopper problems in Asia, a questionnaire was distributed to our Asian partners in China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. This paper summarizes the available data and other information on planthoppers in different Asian countries from 1998 to 2007.

Distribution

Nilaparvata lugens (Stål) is distributed in Asia, Australasia, and the Pacific Islands. In Asia, it is found in Bangladesh, Brunei, Burma (Myanmar), China, Hong Kong, India, Indonesia, Japan, Cambodia, Korea, Laos, Malaysia, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam. In Australia and the Pacific Islands, it is found on the Caroline Islands, Fiji, Mariana Islands, Papua New Guinea, and Solomon Islands (Fig. 1) (Reissig et al 1986, CAB 1984). It is not found in America and Africa. The brown planthopper is mainly a pest of irrigated rice, but it can also be abundant in rainfed environments. It is rare in upland rice (Reissig et al 1986).

Sogatella furcifera (Horvath), or the whitebacked planthopper, is distributed in Asian countries, Australasia, and the Pacific Islands. In Asia, it is found in Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea, Laos, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, Ryukyu Islands, Sri Lanka, Taiwan, Thailand,

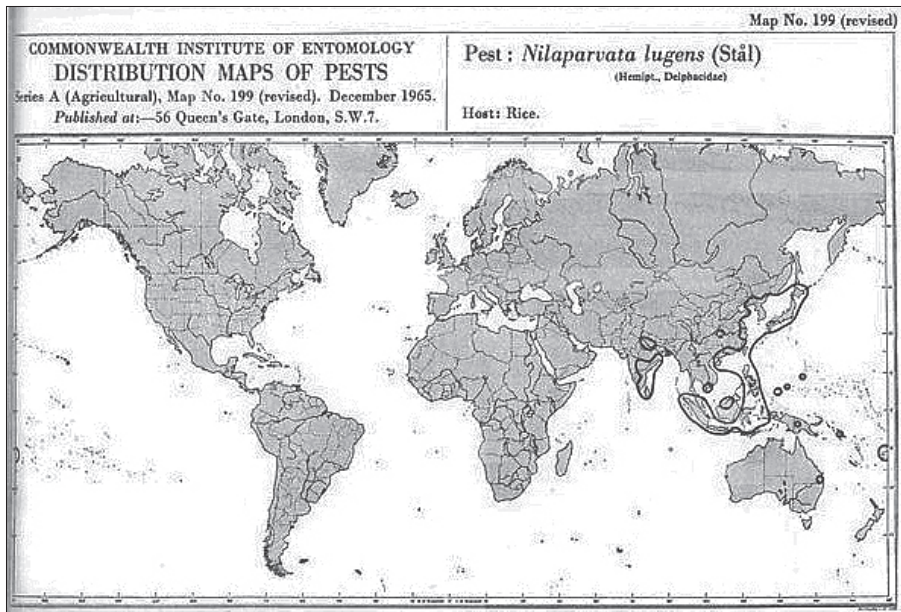


Fig. 1. Distribution map of *Nilaparvata lugens* (Stål) (shown by the black solid lines) (Reissig et al 1986). Reprinted with permission from CABI.

Vietnam, and in the former Soviet Union. In Australasia and the Pacific Islands, it is distributed in Australia, the Caroline Islands, Fiji, Irian Jaya, Marianas Islands, and Marshall Islands (Fig. 2) (Reissig et al 1986, CAB 1980). The whitebacked planthopper is also not found in America and Africa. It occurs in all rice environments (Reissig et al 1986).

Historical trends of distribution

Relative abundance of planthoppers

Light trap catches of BPH. Light trap catches of brown planthoppers from China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam have indicated strong fluctuation patterns over the last 10 years (Fig. 3, Table 1). Comparisons on the data between countries are not applicable since different countries show different trends.

In the five rice regions in China (Nantong City, Jinhua City, Yangtze River rice region, central China rice region, and southern China rice region), the general trend of light trap catches is toward increasing BPH populations over the last 10 years (Fig. 3). Starting from 1998 to 2003, the average of brown planthopper populations has risen and fallen. Within these periods, the lowest population of 1,791 BPH was recorded in 2002 and the highest population of 6,800 BPH was observed in 1999. Based on the highest catch of 1999, there were about 15% more brown planthoppers in 2006 and 2007. There were 103,211 BPH in 2006 and 102,084 in 2007 (Table 1).

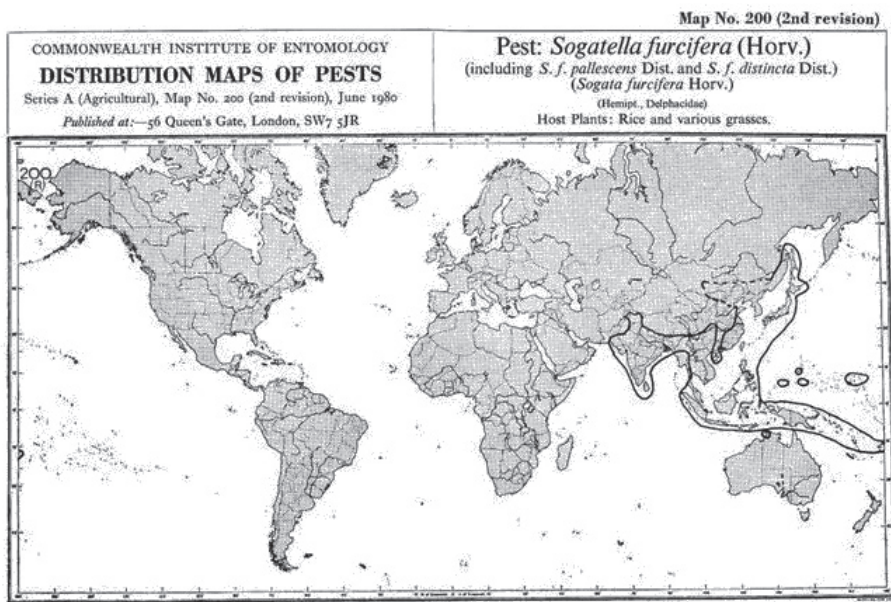


Fig. 2. Distribution map of *Sogatella furcifera* (Horvath) (shown by the black solid lines) (Reissig et al 1986). Reprinted with permission from CABI.

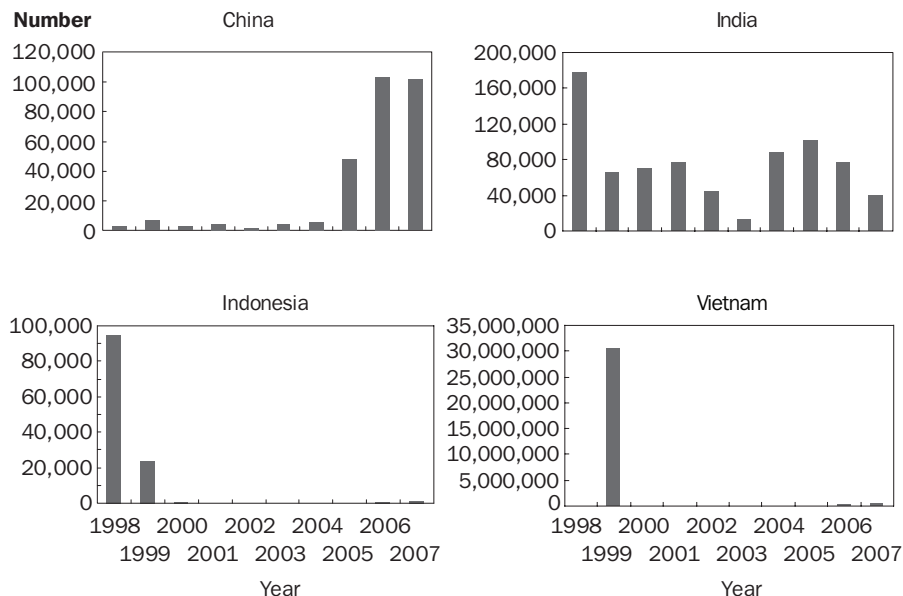


Fig. 3. Number of brown planthoppers from light trap catches in some Asian countries.

Table 1. Number of *Nilaparvata lugens* caught from yearly light trap catches in some Asian countries in 1998-2007.

Year	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
1998	2,207	177,283	94,562	No data	No data	No data	93,057
1999	6,800	65,561	23,617	No data	3,939	2,526,546	30,409,002
2000	2,785	69,989	350	No data	4,184	20,165	18,747
2001	3,734	76,514	9	No data	19,739	194,917	12,317
2002	1,791	44,774	48	No data	18,056	2,484,789	22,008
2003	3,750	12,973	60	No data	No data	No data	47,321
2004	6,063	88,469	24	No data	No data	No data	34,637
2005	47,800	100,689	49	No data	No data	No data	105,057
2006	103,211	75,672	362	No data	No data	297,047	158,356
2007	102,084	39,699	1,008	No data	1,322	194,155	512,141

In six cities in India (Aduthurai, Coimbatore, Maruteru, Sambalpur, Kaul, and Pattambi), the trend in BPH catches was of a decreasing nature during 1998 to 2003, while it was increasing from 2003 to 2005 (Fig. 3). From 2005 to 2007, the BPH population tended to decrease. There were more BPH observed in the 1990s than in the 2000s. The yearly catches decreased by 2.3% in 2006 and 4.5% in 2007. There were only 39,699 BPH trapped in 2007, which was the second lowest sample observed in the past 10 years (Table 1).

In Indonesia, especially in Sukamandi of the north coastal region of West Java, starting from a high population of 94,562 in 1998, the trend in light trap catches was decreasing until 2004 (Fig. 3, Table 1). The BPH population started to pick up from 2005 to 2007. Based on the catch in 1998, there was a 93% reduction in the BPH population in 2007.

In the Philippines, covering Muñoz, Isabela, and Agusan provinces, the BPH population was 5 to 4 times higher in 2001 (19,739 catches) and 2002 (18,056 catches) than in 1999 (3,939 catches) and 2000 (4,184 catches), respectively. In 2007, only one province was sampled; hence, a low population of BPH was recorded at 1,322 counts (Table 1).

In Thailand, the most BPH were observed in 1999 and 2002, when the population was 2.5 million (Table 1). No data on light trap catches were available from 2003 to 2005. The population declined heavily in 2006 and 2007 by more than 2.2 million and 2.3 million, respectively.

In Vietnam, an abnormal trend in BPH populations was observed in the last 10 years (Fig. 3, Table 1). Considering the very high catch in 1999 (30.4 million), the BPH population suddenly went down in 2000 to 2007. Although the BPH population was five times more in 2007 (512,141 individuals) than in 1998 (93,057 individuals), the trend is still toward an abnormal one.

Table 2. Number of *Sogatella furcifera* caught from yearly light trap catches in some Asian countries in 1998-2007.

Year	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
1998	9,139	No data	0	No data	No data	No data	No data
1999	13,318	10,418	0	No data	1,632	No data	No data
2000	16,867	29,350	4	No data	604	No data	No data
2001	12,023	10,057	1	No data	2,231	No data	No data
2002	12,619	14,065	0	No data	9,396	No data	No data
2003	27,852	5,652	22	No data	No data	No data	No data
2004	8,930	2,260	5	No data	No data	No data	No data
2005	59,998	8,020	7	No data	No data	No data	No data
2006	56,720	9,692	202	No data	No data	154	No data
2007	112,993	11,762	601	No data	1,138	237	No data

No data on light trap catches were available for Malaysia.

Light trap catches of WBPH. In the five rice regions in China (Nantong City, Jinhua City, Yangtze River, central China, and southern China), 112,993 WBPH were sampled in 2007, which was almost 13 times more than those obtained during 1998 (9,139 individuals) (Table 2). The lowest population of 8,930 WBPH was observed in 2004. The general trend in light trap catches of WBPH in China has been increasing for the last 10 years (Fig. 4).

In India (Aduthurai, Maruteru, Sambalpur, Kual, and Nawagam), the greatest number of WBPH was observed in 2000, with 29,350 in the light traps. In 2003, 5,652 WBPH were caught and this number declined by almost half in 2004. It gradually increased by 4% in 2005 to 6% in 2007, which is almost half of the WBPH sampled in 2000 (Table 2). The trend in catches was fluctuating (increasing from 1999 to 2000, decreasing from 2000 to 2001, increasing from 2001 to 2002, decreasing from 2002 to 2004, and finally increasing from 2004 to 2007) (Fig. 4).

Indonesia had more whitebacked planthoppers in 2007 (601 individuals) in susceptible varieties. However, the data on light trap catches for WBPH showed fewer catches for the past 10 years despite an increasing trend in the population (Table 2). Visual counts of WBPH in the field showed higher populations in susceptible varieties (Baehaki 2008).

In the three provinces in the Philippines, the most catches (9,396 WBPH) were recorded in 2002 and the least (604) in 2000 (Table 2). In one province, a catch of 1,138 was recorded in 2007.

Only two observations on light trap data were available in Thailand. Some 154 WBPH were caught in 2006, whereas 237 WBPH were trapped in 2007. A difference of 83 counts in the WBPH population was obtained in the two years, with 2007 having the highest count.

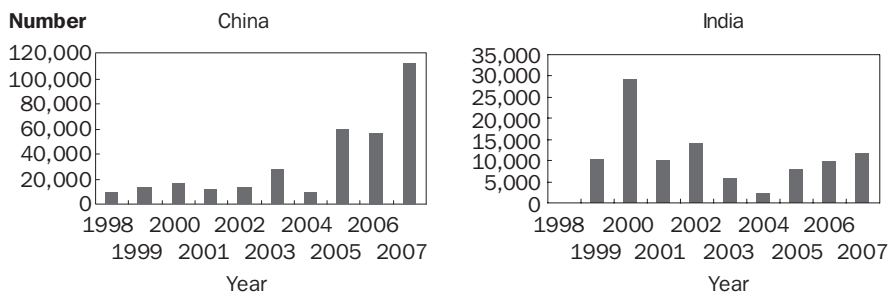


Fig. 4. Number of whitebacked planthoppers from light trap catches in some Asian countries.

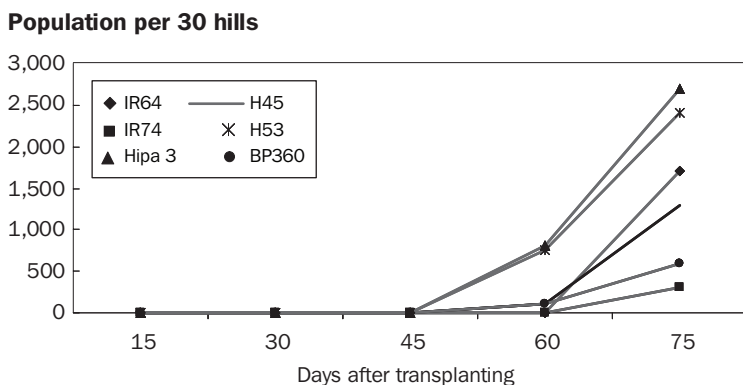


Fig. 5. Population of brown planthopper on hybrid and inbred rice, Subang, West Java, WS 2005.

No data on light trap catches were available for Malaysia and Vietnam.

Other sampling data for planthoppers. In Indonesia, during the wet season in 2005, the brown planthopper was observed to develop more on hybrid rice than on inbred rice (Fig. 5). At 60 and 75 days after transplanting, there were more BPH on hybrids (Hipa 3, H53, and line H45) than on inbreds (IR64, IR74, and line BP360). The same results were recorded for whitebacked planthopper during the dry season of 2004 (Fig. 6). More WBPH were found to develop on hybrid rice (Rokan, Hipa 3, and Hipa 4) than on inbred rice (IR64 and BP360E) from 2 to 7 weeks after transplanting.

In the Philippines, during the 2006 and 2007 DS and WS, planthoppers were collected in Central Luzon, using four sampling devices—visual count, yellow pan trap, window trap, and yellow board trap (Figs. 7 and 8). Most of the time, there were more WBPH than BPH collected from the four sampling devices. The trend was noticeable during the four cropping seasons. There were more BPH (37 individuals) and WBPH (81 individuals) caught in yellow board traps at 52 and 45 DAT, respectively,

Population per 30 hills

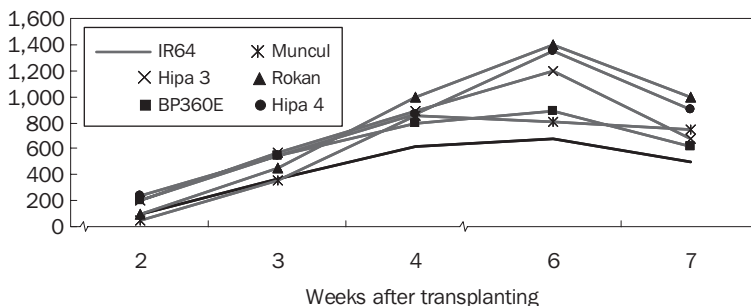
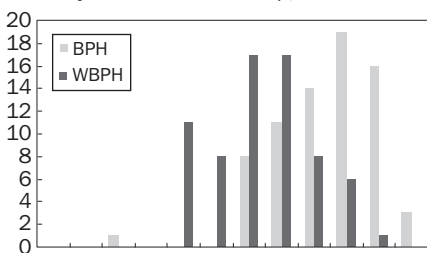
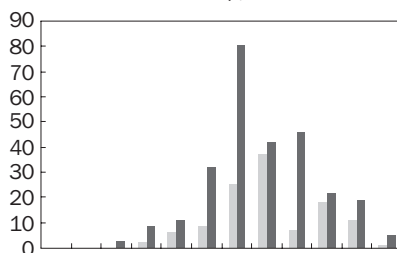


Fig. 6. Population of whitebacked planthopper on hybrid rice, Karawang, West Java, DS 2004.

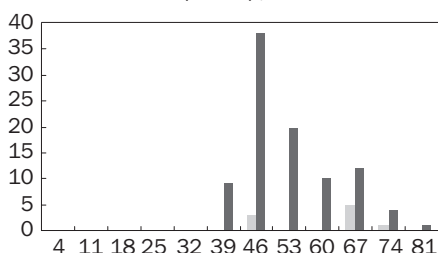
No. trap⁻¹ Yellow board trap, 2006 DS



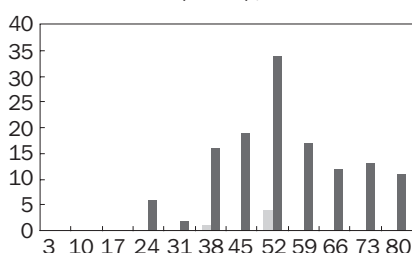
Yellow board trap, 2006 WS



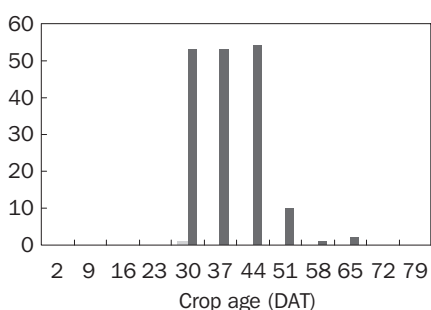
Yellow pan trap, 2006 DS



Yellow pan trap, 2006 WS



No. 10 hills⁻¹ Visual count, 2006 DS



Visual count, 2006 WS

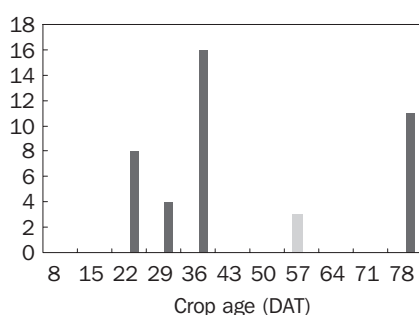


Fig. 7. Observations on planthoppers in 2006 DS and WS, Philippines, using different sampling techniques.

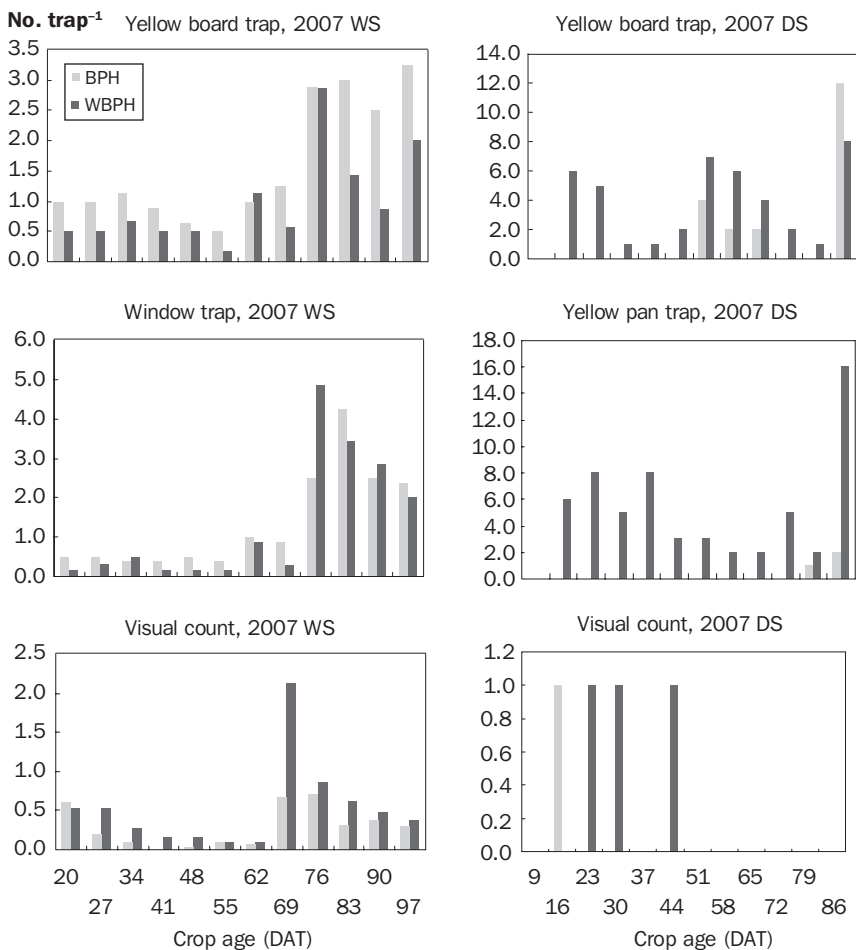


Fig. 8. Observations on planthoppers in 2007 DS and WS, Philippines, using different sampling techniques.

than on the yellow pan trap (4 BPH, 19 WBPH) during the 2006 WS (Figs. 7). In the same season, there were 16 WBPH and 3 BPH per 10 hills counted visually at 36 and 57 DAT, respectively. In the 2006 DS, only 1 BPH was visually collected at 30 DAT with 0 BPH at all the other sampling times and 54 WBPH at 44 DAT (Fig. 6). More WBPH (38 individuals) were collected in yellow pan traps at 46 DAT than on yellow board traps. However, there were more BPH (19) collected on yellow board traps at 67 DAT than on yellow board traps (Fig. 7). In the 2007 WS, considering the total number of planthoppers collected, there were more planthoppers in the window trap sampling device than on the yellow board trap (Fig. 8). There were more WBPH (16) on yellow pan traps at 86 DAT, but more BPH (12) on yellow board traps at 86 DAT in the 2007 DS. Visually, only 1 BPH was recorded at 16 DAT and 1 WBPH at

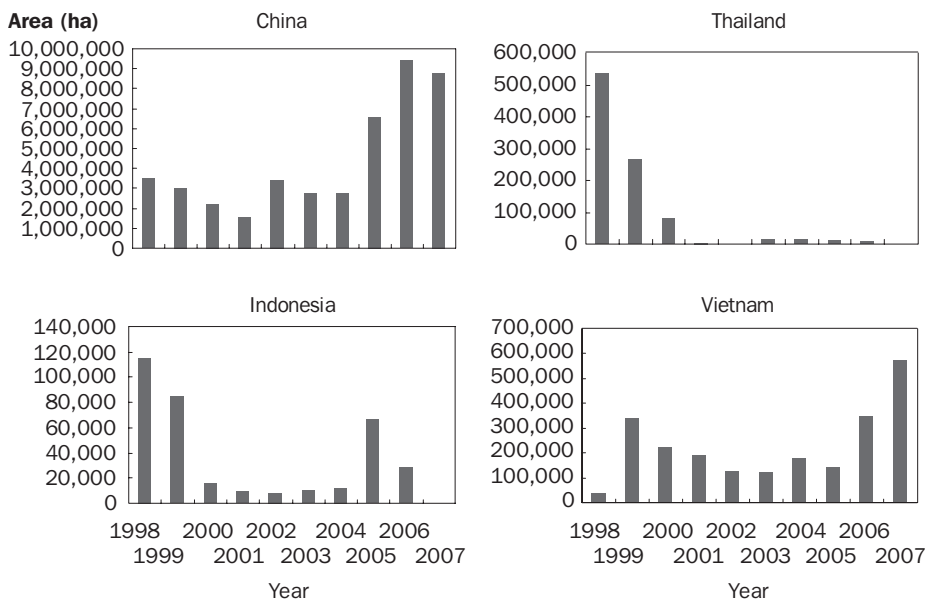


Fig. 9. Damage (in hectares) in rice fields caused by brown planthoppers.

23, 30, and 44 DAT. During the 2007 WS, there were more WBPH counted visually at 69 DAT, and 4.86 were collected on window traps at 76 DAT. Using the yellow board trap, more BPH (3.25) were trapped than WBPH (Fig. 8).

Damage to the rice crop

Planthoppers cause plants to wilt, a symptom called hopper burn. The damage from hopper burn that they caused was documented in some Asian countries from 1998 to 2007 (Fig. 9, Tables 3 and 4). Different trends of damage were observed in different countries.

Damage by BPH. In China, millions of hectares of rice fields were observed with BPH damage every year for the last 10 years (Fig. 9, Table 3). The biggest damage of 9.4 million hectares and 8.7 million hectares was observed in 2006 and 2007, respectively. The general damage trend is increasing.

In Indonesia, BPH damage decreased from 1998 to 2004, but it suddenly increased in 2005, but decreased in 2006 (Fig. 9). The least and maximum areas with hopper-burn damage were 8,573 ha in 2002 and 115,484 ha in 1998. In 2006, there were 28,421 ha of damage recorded, which was 13% less than the observed damage in 1998 (Table 3).

In Malaysia, there was not much difference in the damage area caused by BPH per year. The greatest damage observed was 7,259 ha in 2002 and the least was 3,708 ha in 1999 (Table 3). There were no data on damage from 2003 to 2007.

Beginning in 1998, the highest damage of 535,190 ha was recorded in Thailand (Table 3). Surprisingly, this declined heavily in 2007, when the damage area was only

Table 3. Area (ha) damage to the rice crop by brown planthoppers in some Asian countries in 1998-2007.

Year	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
1998	3,487,850	No data	115,484	4,964	No data	535,190	35,358
1999	3,030,300	No data	84,491	3,708	No data	263,725	341,994
2000	2,196,600	No data	15,910	4,193	No data	81,028	224,411
2001	1,594,550	No data	8,949	5,541	No data	3,328	189,574
2002	3,412,700	No data	8,573	7,259	No data	1,346	128,221
2003	2,725,000	No data	10,350	No data	No data	15,004	120,072
2004	2,735,100	No data	11,844	No data	No data	14,376	176,257
2005	6,588,500	No data	65,908	No data	No data	9,881	145,833
2006	9,418,650	No data	28,421	No data	No data	7,904	348,927
2007	8,751,500	No data	No data	No data	No data	64	572,419

Table 4. Area (ha) damage to the rice crop by the whitebacked planthopper in some Asian countries in 1998-2007.

Year	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
1998	6,903,500	No data	No data	0	No data	No data	No data
1999	6,850,500	No data	No data	1,256	No data	14,905	No data
2000	6,728,100	No data	No data	1,235	No data	No data	No data
2001	6,093,250	No data	No data	541	No data	1	No data
2002	5,134,350	No data	No data	1,068	No data	No data	No data
2003	6,661,450	No data	No data	No data	No data	No data	No data
2004	7,956,600	No data	No data	No data	No data	No data	No data
2005	7,679,400	No data	No data	No data	No data	No data	No data
2006	8,584,900	No data	No data	No data	No data	No data	No data
2007	1,500,000	No data	No data	No data	No data	No data	No data

64 ha, the least recorded in Thailand. The general trend of damage was decreasing.

In Vietnam, the highest damage was 348,927 ha in 2006 and 572,419 ha in 2007 (Table 3). The general trend in damage is sloping. There was a decreasing trend from 1999 to 2003 and an increasing trend from 2003 to 2007 (Fig. 9).

No data on area damage in hectares were available for India and the Philippines.

Damage by WBPH. In terms of the damage caused by whitebacked planthoppers, some data were gathered from China, Malaysia, and Thailand (Table 4). In China,

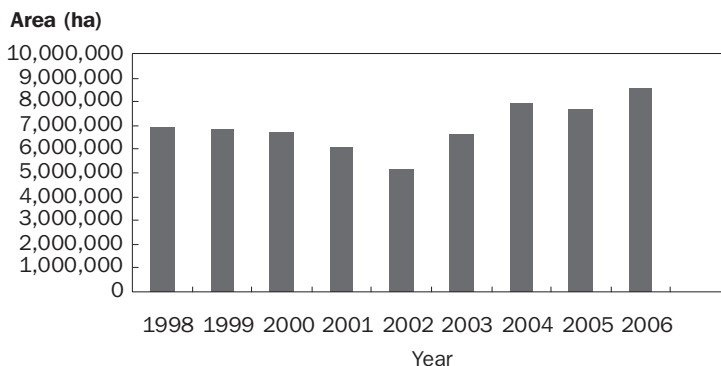


Fig. 10. Damage (in hectares) in rice fields caused by whitebacked plant-hoppers in China.

millions of hectares of rice area were damaged by WBPH every year for the past 10 years. For example, covering five regions in China, 5.1 million ha were the least observed damage (in 2002), with 8.5 million ha being the greatest observed damage (in 2006). In 2007, 1.5 million ha of damage covered only one province. The general trend is increasing (Fig. 10).

In Malaysia, the lowest area damage was 541 ha in 2001, with 1,256 ha being the largest area damage in 1999 (Table 4). There were no available data from 2003 to 2007.

Thailand provided only limited data on the damage caused by WBPH (14,905 ha in 1999 and 1 hectare in 2001).

No data were available on area damaged by whitebacked planthoppers in India, Indonesia, the Philippines, and Vietnam.

Comparison of the damage by the two planthoppers in China showed that whitebacked planthoppers damaged more area than brown planthoppers for the last 10 years (Tables 3 and 4).

Occurrence of insecticide resistance

The excessive use of insecticides led to the development of insecticide resistance to brown planthopper and whitebacked planthopper in the tropics and in temperate Asian countries (Heinrichs 1994). China, India, Indonesia, and Thailand had reports of rice planthopper resistance to insecticide (Fig. 11, Table 5).

In China, planthoppers exhibited 28.8-fold and 79.1- to 81.1-fold resistance to buprofezin and imidacloprid, respectively, in 2004 and 2005 to 2006.

In India, common organophosphates were tested against planthoppers in 1998. However, the planthoppers did not show any significant resistance to the chemical. Other tests in 2006 took place that showed planthopper resistance by 35.13-, 10.78-, and 4.98-fold to imidacloprid, thiamethoxam, and clothianidin, respectively.

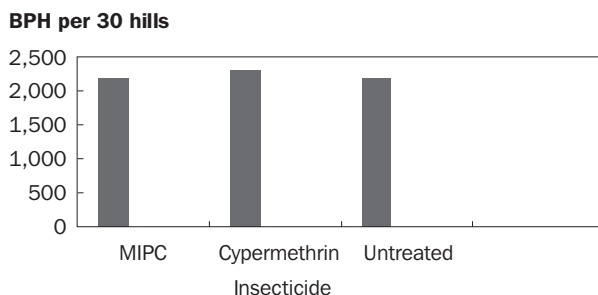


Fig. 11. Effectiveness of insecticides for brown planthopper, Karawang, West Java, 2001.

Table 5. Rice insecticide use in Asian countries showing resistance to planthoppers.

Year	Country	Chemical(s)	Description	References
1998	India	Common organophosphates	No significant resistance	Sarupa et al (1998)
2002	Thailand	Fenobucarb	3–5.6 times resistance	
2004	China	Buprofezin	28.8-fold resistance	Li et al (2008)
2005-06	China	Imidacloprid	79.1–81.1-fold resistance	Wang et al (2008), Liu and Han (2006)
2006	India	Imidacloprid	35.13-fold resistance	Krishnaiah et al (2006), IRC poster presented.
		Thiamethoxam	10.78-fold resistance	
		Clothianidin	4.98-fold resistance	
	Thailand	Imidacloprid	3–4.1 times resistance	

In Indonesia, MIPC and cypermethrin were tested for the brown planthopper. The insect population increased more than the control when cypermethrin was sprayed (Fig. 11).

In Thailand, planthoppers were 3 to 5.6 times more resistant to fenobucarb and 3 to 4.1 times more resistant to imidacloprid when tested in 2002 and 2006, respectively.

Imidacloprid is the common insecticide in China, India, and Thailand against which planthoppers have developed resistance. No data on insecticide resistance were available in Malaysia, the Philippines, and Vietnam.

Table 6. Planthopper management options in some Asian countries.

Country	Management options
China	Insecticides (buprofezin, Imidacloprid, fipronil, chlorpyrifos, DDVP) Rearing and releasing ducks in paddy Rice-fish double-culture systems Adjusting planting date Using insect-net proofs in nursery Light trapping Management of BPH resistance to imidacloprid
India	Summer plowing Clipping leaf tips of seedlings before transplanting Optimum dose of N application Leaving alleyways at 5-meter intervals Avoiding broad-spectrum insecticides Draining water during mid-season Wider spacing Resistant varieties Need-based insecticides
Indonesia	Monitoring Resistant varieties (IR64, IR74, Ciherang, Digul, Fatmawati, Membramo, and Mekongga) Use of economic threshold Insecticides (industrial or company and botanical) Manipulation of natural enemies Cultural practices (intermittent irrigation, weeding, varietal rotation, and fertilizer management)
Malaysia	Monitoring Use of insecticides
Thailand	Resistant varieties (Pathum Thani 1, Suphanburi 1, Suphanburi 2, Suphanburi 90, Chainat 1, Chainat 2, and Phisanuloke 2) Recommended insecticides (imidacloprid, dinotefuran, thiamitozam, buprofezin, carbosulfan, and isoprocarb) Surveillance and survey sampling of BPH and rice ragged stunt diseases Eradication and destruction of rice ragged stunt plants and their platoon Eradication of weeds that are hosts of rice ragged stunt virus

Management of planthoppers

A list of management options for planthoppers was provided by China, India, Indonesia, and Thailand (Table 6). The predominant management option for planthoppers today in most countries continues to rely solely on insecticide.

Except for China, the use of resistant varieties is common to India, Indonesia, and Thailand. It is only in Indonesia that natural enemies are used as part of the management program for planthoppers.

Research activities

Studies on planthoppers are conducted continuously in Asian countries because of the threat they pose to rice production (Tables 7 and 8). Most of the research activities on BPH and WBPH focus on insecticide screening and varietal screening. Comparing the number of research activities between the two hopper species, more work is conducted on BPH than on WBPH.

In order of publications, more works were published on insecticide screening, followed by varietal screening, virulence, biotypes, ecological fitness, pest management, nutrient management, and modeling of planthopper damage (Table 9).

Table 7. List of research activities conducted on brown planthopper or its associated viruses in some Asian countries in 1998-2007.

Country	Years	Research activity
China	1996-2007	Forewarning system for catastrophes of the main rice diseases and pests Forewarning parameters for catastrophes of migratory pests and on national catastrophes Forewarning and decision support system for pernicious living beings Development on monitoring and forewarning techniques for major diseases and pests Fundamental research on catastrophe forewarning, ecological adjustment, and control of diseases and pests Fundamental research on rampant endangering mechanisms of major agricultural pests and their sustainable control Study on atmospheric dynamical mechanisms for catastrophic immigrations of brown planthoppers Monitoring the virulence shift of BPH to rice varieties with different resistance genes Screening resistance to BPH of rice varieties (lines) in both greenhouse and fields Relationship between planthoppers and biodiversity around paddy field The role of endosymbiosis of BPH in its adaptation to resistant rice varieties The interaction of nitrogen fertilizer and high temperature on ecological fitness of BPH
India	1998-2007	Screening rice germplasm accessions and breeding lines for resistance Identifying effective insecticides Biocontrol agents IPM Evaluating transgenic lines with GNA gene Genetics of resistance

Continued on next page

Table 7 continued.

Country	Years	Research activity
Indonesia	1998-2007	<p>Damage level of planthopper and rice stem borer attacks on transplanted and direct-seeded rice</p> <p>Identification of BPH biotypes and rice damage on upland rice area</p> <p>Impact of nutrient management on pest and yield losses of different rice varieties</p> <p>Augmentation technique for raising efficacy of <i>Metarhizium anisopliae</i> with additive material</p> <p>Efficacy of <i>Beauveria bassiana</i> RIRCC2 on adjuvant material to BPH in the laboratory</p> <p>Assessment on decreasing yield losses based on scoring damage by BPH and WBPH</p> <p>Virulence and assessment of BPH biotypes from central Java</p> <p>Distribution of BPH biotypes on some central rice production areas</p> <p>Evaluation of components of resistance on lines and varieties to BPH biotypes 3 and through filtering test and population buildup</p>
Malaysia	1990-2003	<p>Population dynamics of <i>Nilaparvata lugens</i> in rice</p> <p>The role of spatial heterogeneity on population dynamics of major rice pests</p>
Thailand	1998-2004	<p>Development of resistance to carbofuran, BPMC, etofenprox, and buprofezin in brown planthopper</p> <p>Effect of recommended granular insecticides for controlling stem borers, leaffolder, and brown planthopper on different resistant rice varieties</p> <p>Study on appropriate dosage of recommended insecticides for controlling resistant strains of BPH</p> <p>Effect of recommended granular insecticides for controlling stem borers, leaffolder, and brown planthopper on Pathum Thani 1, Chai Nat 1, Suphanburi 1, and Khao' Jow Hawm Suphan Buri rice varieties</p> <p>Application technique of recommended foliar spray insecticide to retard insecticide resistance developing in BPH</p> <p>Study of BPH biotypes for improving resistant rice varieties</p> <p>Biology of viruliferous rice ragged stunt, brown planthopper, and healthy brown planthopper</p> <p>Improvement of dot immuno binding assay for rapid detection</p> <p>Relationship among RRSV viruliferous insects</p> <p>Screening of some rice varieties' reaction for RRSV resistance genetic source in rice breeding program</p>
	2005-06	Purification of rice ragged stunt virus and antiserum production

Table 8. List of research activities conducted on whitebacked planthoppers in some Asian countries in 1998-2007.

Country	Years	Research activity
China	2004	The effect of nitrogen on ecological fitness of WBPH
India	1998-2007	Screening rice germplasm accessions and breeding lines for resistance Evaluating transgenic lines with GNA gene
Indonesia	2002	Competition of BPH and WBPH in the same niche
Thailand	1998, 2004	Monitoring and determining insecticide resistance of WBPH collected from rice-planting areas Study of WBPH biotypes for improving resistant rice varieties

Table 9. List of publications on planthoppers in some Asian countries in 1998-2007.

Country	Year and title
China	1998. The virulence characteristics of various populations of brown planthopper. <i>J. Southwest Agric. Univ.</i> 20(5):446-449.
	1997. Variation in virulence of the brown planthopper to resistant rice varieties and its relation to the changes in the activities of endogenous enzymes. <i>Entomol. Sin. (Suppl.)</i> 40:122-127.
	1999. On the brown planthopper resistance in introgressive lines from wild rice. <i>Acta Phytophyl. Sin.</i> 26(3):197-202.
	1999. Study on brown planthopper control tactic in the middle-late non-glutinous rice zone. <i>J. Nanjing Agric. Univ.</i> 22(1):42-45.
	1999. Study on resistance to brown planthopper <i>Nilaparvata lugens</i> (Stål) in indica hybrid rice. <i>Acta Agric. Zhejiangensis</i> 11(4):163-166.
	1999. The second male vibrational signal of brown planthopper <i>Nilaparvata lugens</i> (Stål) and its significance in competitive reproductive behaviour. <i>Acta Entomol. Sin.</i> 42(1):1-6.
	1999. The tolerance differences of brown planthopper biotypes to adverse environmental factors. <i>Acta Agric. Zhejiangensis</i> 11(6):301-305.
	1999. The different feeding and oviposition behavior among brown planthopper biotypes. <i>Acta Phytophyl. Sin.</i> 203-207.
	1999. Virulence to resistant rice varieties of brown planthopper populations from fields and greenhouse. <i>Chinese J. Rice Sci.</i> 13(1):46-48.
	1999. The virulence changes and damage characteristics of different geographic populations of brown planthopper. <i>Entomol. Sin.</i> 6(2):146-154.
	2000. Effects of high temperature on juvenile hormone esterase activity in brown planthopper, <i>Nilaparvata lugens</i> (Stål). <i>J. Nanjing Agric. Univ.</i> 23(2):114-115.
	2000. Tolerance of various geographic populations of brown planthopper to adverse environmental stresses. <i>Chinese J. Appl. Ecol.</i> 11(5):745-748.

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Table 9 continued.

Country	Year and title
	2000. The effect of submerging rice plants on the survival and fecundity of brown planthopper at different temperatures. <i>Acta Ecol. Sin.</i> 20(4):624-628.
	2001. Chaos and predictable time-scale of the brown planthopper <i>Nilaparvata lugens</i> (Stål) occurrence. <i>Syst. J. Asia-Pacific Entomol.</i> 4(1):67-74.
	2001. Intra- and inter-specific effects of the brown planthopper and whitebacked planthopper on their population performance. <i>J. Asia-Pacific Entomol.</i> 4(1):85-92.
	2001. The differentiation of amino acid requirements in three host related populations of the brown planthopper, <i>Nilaparvata lugens</i> (Stål). <i>Acta Entomol. Sin.</i> 8(4):361-369.
	2002. Resistance of rice varieties to brown planthopper <i>Nilaparvata lugens</i> Stål. <i>Sci. Agric. Sin.</i> 35(2):225-229.
	2001. The population dynamics of endosymbionts in body of brown planthopper from different geographic fields and adapted to different resistant rice varieties. <i>Entomol. J. East China</i> 10(1):44-49.
	2001. Effects of endosymbiont on feeding, development, and reproduction of brown planthopper, <i>Nilaparvata lugens</i> Stål. <i>Chinese Rice Res. Newsl.</i> 9(2):11-12.
	2001. Bionomics of brown planthopper biotype 2 collected in field and greenhouse. <i>Chinese Rice Res. Newsl.</i> 9(4):9.
	2001. The effect of endosymbiont on the development and reproduction of brown planthopper, <i>Nilaparvata lugens</i> Stål. <i>Acta Phytophyl. Sin.</i> 28(3):193-197.
	2001. The role of endosymbiont in virulent shift of brown planthopper. <i>Acta Ecol. Sin.</i> 44(2):197-204.
	2002. Behavioral responses of brown planthopper and white-backed planthopper to BPH-resistant rice varieties. <i>Acta Phytophyl. Sin.</i> 29(2):145-152.
	2002. The biological characteristics of biotype 2 of brown planthopper populations from greenhouse and paddy fields. <i>Chinese J. Rice Sci.</i> 16(1):89-92.
	2002. Evaluation for resistance levels of newly-bred rice varieties (lines) to brown planthopper <i>Nilaparvata lugens</i> Stål in China. <i>Agric. Sci. China</i> 1(3):323-327.
	2004. Effects of temperature on population growth of susceptible and resistant strains of <i>Nilaparvata lugens</i> to imidacloprid. <i>Entomol. Knowl.</i> 41(1):47-50.
	2004. Predatory behavior of mirid bug, <i>Cyrtorhinus lividipennis</i> , on rice plants with different nitrogen regimes. <i>Int. Rice Res. Notes</i> 29(2):32-34.
	2004. Effect of nitrogen nutrient on the ecological fitness of brown planthopper, <i>Nilaparvata lugens</i> Stål, on rice cultivar IR64. In: <i>Plant protection towards the 21st century. Proceedings of the 15th International Plant Protection Congress, Beijing, China, 11-16 May 2004.</i> p 315.

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Table 9 continued.

Country	Year and title
	2004. Dynamics of yeast-like symbionte and its relationship with the virulence of brown planthopper, <i>Nilaparvata lugens</i> Stål, to resistant rice varieties. <i>J. Asia-Pacific Entomol.</i> 7(3):317-323.
	2004. Effect of nitrogen on water content, sap flow of rice plants in association with tolerance of brown planthopper. <i>Chinese J. Rice Sci.</i> 18(2):105-111.
	2004. Effects of plant nitrogen on ecological fitness of the brown planthopper, <i>Nilaparvata lugens</i> Stål, in rice. <i>J. Asia-Pacific Entomol.</i> 7(1):97-104.
	2004. Effect of nitrogen on water content, sap flow, and tolerance of rice plants to brown planthopper, <i>Nilaparvata lugens</i> . <i>Rice Sci.</i> 11(3):129-134.
	2005. Planthopper damage to rice and the resurgence mechanism. <i>Chinese Bull. Entomol.</i> 2(6):612-615.
	2005. Progress in the histological studies of the intracellular yeast-like symbiotes in rice planthoppers. <i>Chinese Bull. Entomol.</i> 42(6):607-611.
	2005. Effects of nitrogen on the tolerance of brown planthopper, <i>Nilaparvata lugens</i> , to adverse environmental factors. The 5th Asia-Pacific Congress Entomology—Insects, Nature, and Humans, Jeju, Korea.
	2005. Effects of nitrogen on the tolerance of brown planthopper, <i>Nilaparvata lugens</i> , to adverse environmental factors. <i>Insect Sci.</i> 12:121-128.
	2005. Effects of nitrogen content in rice plants and densities on the survival, development and reproduction of brown planthopper. <i>Acta Ecol. Sin.</i> 25(8):1838-1843.
	2005. Effect of nitrogen fertilizer in rice fields on the predatory function of <i>Cyrtorhinus lividipennis</i> to brown planthopper. <i>Acta Entomol. Sin.</i> 48(1):48-56.
	2005. Effect of nitrogen nutrient on the behavior of feeding and oviposition of brown planthopper on IR64. <i>J. Zhejiang Univ. (Agric. & Life Sci.)</i> 31(1):62-70.
	2006. Occurrence and ovipositing characteristics of <i>Nilaparvata lugens</i> on scented rice. <i>Chinese Bull. Entomol.</i> 43(4):466-469.
	2006. Biodiversity and dynamics of planthoppers and their natural enemies in rice fields with different nitrogen regimes. <i>Rice Sci.</i> 3(3): 218-226.
	2006. Impact of nitrogen fertilizer on natural control capacities of invertebrate predators and parasitoids and its demonstration in rice-based ecosystem. <i>Acta Agric. Zhejiangensis</i> 18(2):128-132.
	2006. Dynamics of predators in rice canopy and capacity of natural control on insect pests in paddy fields with different nitrogen regimes, <i>Acta Phytophyl. Sin.</i> 33(3):225-229.
	2007. Effect of nitrogen fertilizer in rice fields on the predatory function of <i>Cyrtorhinus lividipennis</i> to brown planthopper. <i>Proc. China Assoc. Sci. Tech.</i> 4(1):571-577.
	2007. Effect of nitrogen fertilizer on herbivores and its stimulation to major insect pests in rice. <i>Rice Sci.</i> 14(1):56-66.

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Table 9 continued.

Country	Year and title
India	1998-2007. Progress report of AICRIP, v. 2.
Indonesia	1998. Damage level of planthopper and rice stem borer attacks on transplanted and direct seeded rice (Tingkat serangan Hama wereng dan Penggerek padi pada Tapin dan Tabela di dua golongan air pengairan). Prosiding Seminar Peningkatan Produksi Padi Nasional melalui sitem tabela padi sawah dan pemanfaatan lahan kurang produktif. p 122-127 (with English summary).
	2001. Identification of BPH biotype and rice damage on upland rice area (Identifikasi Biotipe Wereng Coklat dan Kerusakan Padi pada Tanaman Tumpangsari di Lahan Padi Gogo). Implementasi Kebijakan Strategis untuk Peningkatan Produksi Padi Berwawasan Agribisnis dan Lingkungan. Indonesian Center for Food Crops Seminar. p 149-154.
	2001. Impact of nutrient management on pest and yield losses of different rice varieties. Workshop and Data Analysis and Synthesis Relationship between Multiple Pests and Yields. Zhejiang University, Hangzhou, China. 10 p.
	2002. Level of eggs BPH parasitizing by <i>Anagrus</i> and <i>Oligosita</i> on two varieties and different pattern system (Tingkat Parasitasi Telur Wereng Coklat oleh <i>Anagrus</i> dan <i>Oligosita</i> pada dua Varietas dan Sistem tanam yang Berbeda). Prosiding Seminar Nasional Biologi XVI dalam rangka Kongres Nasional Biologi XII. Perhimpunan Biologi Indonesia. p 262-265.
	2002. Daya Kompetisi Wereng Coklat dengan Wereng Punggung Putih pada Relung Ekologi yang Sama. Penelitian Pertanian Tanaman Pangan 21(3):41-53 (with English summary).
	2002. Augmentation technique for raising efficacy of <i>Metarhizium anisopliae</i> with additive material (Teknik Augmentasi Peningkatan Efikasi <i>Metarhizium anisopliae</i> dengan Berbagai Zat Aditif Terhadap Wereng Coklat). Report of Indonesian Center for Rice Research.
	2003. Efficacy of <i>Beauveria bassiana</i> RIRCC2 on adjuvant material to BPH in the laboratory (Efikasi <i>Beauveria bassiana</i> RIRCC2 terhadap wereng coklat dengan penambahan zat perekat dan ajuvant di Laboratorium). Report of Indonesian Center for Rice Research.
	2004. Simulation of mosaic rice varieties as a management to reduce BPH development (Simulasi Sistem Pertanaman Padi Multi Varietas Sebagai Alternatif Teknik Mengendalikan Wereng Coklat Serta Profil Varietas Padi Di Lapangan). Seminar of National Rice Week II.
	2005. Assessment decreasing yield losses based on scoring damage by BPH and WBPH (Penilaian Penurunan Hasil Berdasar Skor Kerusakan Akibat Wereng Coklat Dan Wereng Punggung Putih). Prosiding Seminar Nasional dan Kongres Biologi XIII. Yogyakarta. p 351-357.
	2005. Virulent and assessment biotype of BPH from central Java. Keganasan dan penentuan biotipe wereng coklat Jawa Tengah (kasus pati dan demak) terhadap varietas padi yang dilepas. Prosiding Seminar Nasional dan Kongres Biologi XIII. Yogyakarta, 16-17 September 2005. p 726-731.

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Table 9 continued.

Country	Year and title
	2005. Characteristic development of brown planthopper in The North Coastal of West Java on popular rice varieties. Presented at the 1st International Conference of Crop Security 2005. Brawijaya University, Malang, Indonesia. 16 p.
	2007. Distribution of BPH biotype on some central rice production area (Sebaran Biotipe Wereng Coklat Di Beberapa Sentra Produksi Padi). CRIFC Seminar, Bogor, 15 February 2007.
	2007. Evaluation of resistance components on lines and varieties to BPH biotype 3 and through filtering test and population buildup (Evaluasi Komponen Ketahanan Galur Padi Terhadap Wereng Coklat Biotipe 3 Melalui Uji Penapisan Dan Population Buildup). Seminar Apresiasi Hasil Penelitian. p 14. (With English summary.)
	2007. The effect of multiple pests on yield losses in an intensive rice system in Indonesia. Rice industry, culture and environment. Indonesia Center for Rice Research (ICRR). 16 p.
Malaysia	1999. Towards site-specific agriculture of pest management in rice ecosystem. MCB-MAPPS Plant Protection Conference 99. Malaysian Cocoa Board and Malaysian Plant Protection Society. 11-12 November 1999, Kota Kinabalu, Malaysia. p 42-45.
	1995. Modelling planthopper damage mechanism on rice. Paper presented at SARP and SAAD II Symposium. December 1995.
	2000. Quantifying the impact of insecticide application on arthropod diversity in the rice ecosystem. Malaysian Plant Protection Society, 23-24 November 2000. Kuching, Malaysia. p 141-144.
	2000. Precision farming: Can it be applied to manage BPH population in rice ecosystem? Poster presented at MARDI Senior Staff Conference 2000. MARDI and PKKM, 18-19 September 2000, Genting Highland, Malaysia.
	2001. Simulation of brown planthopper damage mechanism on rice. J. Trop. Agric. Food Sci. 29(1):39-51.
	2001. Spatio-temporal distribution of brown planthopper in relation to distribution of their predator <i>Cyrtorhinus lividipennis</i> in two rice granary areas in Malaysia. International Rice Research Conference. MARDI, Alor Star.
	2005. Precision agriculture in integrated pest and disease management. Proceedings National Conference on AgriCT 2005: Revolutionizing Agriculture through ICT, 27-28 September 2005, MARDI, Kuala Lumpur. p 242-249.
	2006. Spatio-temporal distribution of planthopper and predator mirid bug for two rice granary areas in Malaysia. J. Trop. Agric. Food Sci. 33(2):405-416.
Thailand	1998. Development of resistance to carbofuran, BPMC, etofenprox, and buprofezin in the brown planthopper. In: Annual Report of Entomology and Zoology Division. 1998. Division of Entomology and Zoology, Department of Agriculture, Bangkok, Thailand. p 65-77.

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Table 9 continued.

Country	Year and title
	1999. Resistance level to insecticides of whitebacked planthopper, <i>Sogatella furcifera</i> (Horvath). Entomol. Zool. Gazette. 21(1):3-12.
	1999. Resistance level of the mirid bug, <i>Cyrtorhinus lividipennis</i> (Reuter) to recommended insecticides. In: Annual Report of Entomology and Zoology Division, Division of Entomology and Zoology, Department of Agriculture, Bangkok, Thailand. p 118-125.
	2002. Effect of recommended granular insecticides for controlling stem borers, leaffolder, and brown planthopper on Pathum Thani 1, Chai Nat 1, Suphanburi 1 and Khao' Jow Hawm Suphan Buri rice varieties. Entomol. Zool. Gazette. 24(1):17-38.
	2002. Study on appropriate dosage of recommended insecticides for controlling resistance strain BPH. In: Proceedings of Rice Research Conference 2002. Pathum Thani Rice Research Center, Thanyaburi, Pathum Thani, 29 Feb.-1 Mar., Thailand. p 179-200.
	2006. Adaptation to breaking resistant varieties of different populations of brown planthopper from Central and Northern Provinces. In: Proceedings of Rice Research Conference 2006. Rice Research Institute, 28-29 Mar., Cha-um, Petchaburi, Thailand. p 119-128.
	2006. Situation and management of brown planthopper (BPH) in Thailand. In: International Workshop on Ecology and Management of Rice Planthoppers (abstract), Huajiachi Campus, Hangzhou, Zhejiang, China, 16-19 May 2006. p 9-13.
	2006. Production of antiserum for rice ragged stunt virus detection. In: Proceedings of Rice Research Conference 2006. Rice Research Institute, 28-29 Mar., Cha-um, Petchaburi, Thailand. p 95-99.
	2007. Resistance situation of brown planthopper in Thailand. In: International Workshop on Forecasting and Management of Rice Planthoppers in East Asia: Their Ecology and Genetics, 4-5 December 2007. National Agriculture Research Center for Khushu Okinawa Region, Kumamoto, Japan. p 20-26.

A list of current activities on brown planthopper and whitebacked planthopper was provided by China, India, Indonesia, Malaysia, and Thailand (Table 10). The most common activities involve insecticide screening, varietal screening, and biotypes.

Discussion

Nilaparvata lugens and *Sogatella furcifera* have only within the past few decades emerged as important economic pests in Asia (Heinrichs 1994). Asian countries that continue to rely on insecticide for control of the two planthoppers have experienced a reflective increase in the numbers in light trap catches for the last 10 years. Unnecessary insecticide sprays often disrupt the ecological balance in a rice ecosystem,

Table 10. Current research activities in some Asian countries.

Planthopper	Country	Research activity	
BPH	China	Insecticide resistance detection and monitoring in brown planthopper	
		Cross-resistance of imidacloprid resistance in brown planthopper	
		Assessment of biological activity of pymetrozine against brown planthopper	
		Mechanism for imidacloprid resistance in brown planthopper	
		Genetics of imidacloprid resistance in brown planthopper	
		Laboratory screening of alternative insecticides for replacing highly-toxic five-phosphorus insecticides (such as methamidophos, parathion, methyl-parathion, monocrotophos, phosphamidon) for controlling brown planthopper	
		The molecular mechanism in the role of endosymbiosis in adaptation of BPH to resistant rice varieties	
		The impact of global warming on the relationship between planthoppers and their natural enemies	
		Field demonstration of rice varieties resistant to planthoppers and ecological control in insecticide reduction in Jinhua	
		Exploring intercropping plants to enhance parasitoids of planthoppers for insecticide reduction	
		Monitoring for BPH resistance to insecticides	
		India	Screening for resistance
			Genetics of resistance and QTL mapping
			MAS for gene pyramiding for high resistance
		Indonesia	Evaluation of transgenics with GNA and VIP genes
Screening lines and rescreening varieties for BPH biotypes 3 and 4			
Malaysia	BPH development on new hybrids and new plant type in the field		
	Assessment of BPH resistance to insecticides		
	Mapping BPH		
Philippines	Monitoring of rice arthropod diversity in the rice ecosystem		
Thailand	Varietal screening		
	BPH biotypes for improving resistant rice varieties		
	Monitoring and prediction of BPH outbreaks in Central Region		
WBPH	China	Efficacy of insecticides for controlling BPH	
		Assessment of risk of resistance to imidacloprid and buprofezin in whitebacked planthopper	
		Laboratory screening of alternative insecticides for replacing highly-toxic five-phosphorus insecticides for controlling whitebacked planthopper	
		India	Screening for resistance
			Genetics of resistance and QTL mapping
			MAS for gene pyramiding for high resistance
			Evaluation of transgenics with GNA and VIP genes
		Indonesia	WBPH development on new hybrids and new plant type in the field
			Assessment of WBPH resistance to insecticides
		Malaysia	Study on changed WBPH biotype
			Monitor rice arthropod diversity in the rice ecosystem
		Thailand	WBPH biotypes for improving resistant rice varieties

favoring the development of planthoppers. Observations on the population abundance of planthoppers also reflect the area of hopper burn created. Hopper burn was greatest in China.

In sprayed fields like those in China, an increasing trend in planthopper populations was observed for the last 10 years. In Zhejiang Province, farmers constantly use chemicals such as imidacloprid, buprofezin, chlorpyrifos, and fipronil to spray their rice fields. This practice started in Zhejiang in 1998. Imidacloprid, being one of the popular insecticides in China, has been widely used in other rice-growing areas in Vietnam, South Korea, and Japan since the early 1990s (Liang et al 2007). Because of the high control efficiency and cheaper price of insecticides, Chinese farmers were lulled into using 3–5 applications as a main component of a “cocktail insecticide” for every crop. In 2005, the excessive use of this insecticide caused a serious outbreak of BPH because of the development of insecticide resistance in rice planthoppers (Cheng and Zhu 2006). A resurgence of BPH had stimulated its population growth. Although there were some reports on various pesticide resistance problems for rice planthoppers with organophosphates and carbamates (Long 2005), insecticides are still being used in China because of a lack of resistant varieties as well as the perceptions of farmers and technicians on pesticides with regard to timing of application and type of pesticide to be used (Cheng et al 1995). Moreover, field experiments and simulation studies demonstrated that the best strategy is to apply insecticide with higher efficiency and a longer residual period at 30 days after transplanting based on a control threshold in the second rice-cropping season. Another factor causing the increase in the planthopper population in China is the wide adoption of high-yielding hybrid rice since 1976 (Sogawa 2004). Chinese hybrid rice has caused a new pest problem, the whitebacked planthopper. Outbreaks of WBPH were observed because of the high susceptibility of hybrids to *S. furcifera* (Sogawa 2004). Furthermore, the subsequent increase in insecticide applications against WBPH resulted in the development of resistance of this insect pest to pesticide and increased the risk of pest resurgence due to the destruction of natural enemies in paddy fields.

In India, planthopper populations were fluctuating for the last 10 years. Brown planthopper was contained during the mid-1990s through advocating IPM involving the adoption of resistant rice varieties, wider spacing between plants or leaving alleyways every 1–2 meters, optimum nitrogenous fertilizers, and strictly need-based insecticide application. However, the recent increase in their population has been brought about by the different neonicotinoid insecticides that were introduced, which helped growers to successfully manage the BPH (IRAC 2007). But, because of the continuous and indiscriminate use of neonicotinoids over the past few years, frequent control failures by this class of insecticide became evident in the past 2 years, especially in the southern Indian states of Andhra Pradesh and Karnataka. It is possible that BPH has evolved resistance to neonicotinoid chemistry. Other factors that contributed to the BPH outbreaks in rice are the continuous cultivation of susceptible rice varieties such as BPT and Swarna, the high use and even four times the recommended dose of nitrogenous fertilizers, favorable microclimate, favorable conditions for the development of winged black-colored macropterous forms, widespread migration in

endemic areas and new areas, closer planting, and an imbalance between the use of N and K fertilizers (Gudem 2006). Fresh reports on BPH during 2007-08 came from the states of Haryana, Punjab, and Delhi. Popular rice hybrids have shown greater damage. Likewise, WBPH outbreaks were reported prior to 1980 in the northern states and again during 2007-08 pest outbreaks were reported from Himachal Pradesh and Punjab. However, so far, no major reports of virus diseases associated with BPH are on record.

In countries where planthopper outbreaks were minimal or negligible, there is a significant reduction in insecticide use (Huan et al 1999). For example, in Indonesia, there was a relatively low density of planthoppers from light trap catches from 2000 to 2007. The reason may be Presidential Decree 3/86 by President Suharto in 1986 banning most pesticides. This decree also provided the framework and support necessary for farmers to understand and conserve natural enemies. Because of this, it has helped keep rice fields in Indonesia relatively free from brown planthoppers over the past 10 years. Since Indonesia adopted an IPM program in 1986, pesticide production has dropped by more than 50% and the country banned the use of 57 trade formulations of insecticides. Among the Asian partners, Indonesia is the only one using natural enemies as part of its management program for planthoppers. Moreover, an extensive program to educate farmers based on a farmer field school model was implemented (Gallagher et al 2002).

The brown planthopper problem in Malaysia seems to be very small compared with other Asian countries. Nevertheless, it remains an important pest of rice. In the past, devastating outbreaks of planthoppers led to the establishment of a surveillance system in the major rice-growing regions in Malaysia (Ooi 1988). The surveillance system also directed the development of rice planthopper control strategies as well as providing information on optimum time for application of insecticides. Furthermore, when IPM was introduced in Malaysia, it was widely promoted for rice paddies and resulted in a reduction in incidence of pest population explosions, especially severe outbreaks of brown planthoppers and whitebacked planthoppers (Taylor et al 2003). Lately, IPM practices have seemed to slow down. Farmers tend to return to insecticide sprays to “protect” their rice fields from brown planthopper outbreaks. A survey carried out by Normiyah in 1995 showed that 47% of farmers in the Muda area sprayed their fields during the first 30 days after sowing.

In the Philippines, in 2002, there was a report of brown planthopper infestation in Camarines Sur accounting for 173.5 affected hectares (Umasenso 2002). Since then, no other heavy infestations caused by planthoppers were reported. This may be due to the low insecticide use in the Philippines. There are two main factors for this low insecticide use—the education campaign based on research findings from entomologists at UPLB, PhilRice, IRRI, and other organizations have convinced farmers of the dangers of pesticide use, and insecticide prices are relatively high in the Philippines unlike the two to six times higher prices in Thailand, Vietnam, India, and China (Dawe 2002). Likewise, the government of the Philippines actively encouraged farmers to give up the wholesale use of pesticides and to follow a system of integrated pest management that included growing resistant strains of rice, maintaining a pool of

natural predators, and resorting to chemicals only when pests reached a certain level. With pesticide reduction, agricultural biodiversity is enriched due to the increase in beneficial insect populations. This provides an ecological balance that is conducive to sustainable farming (The Philippines 1996).

Though a relatively low population of planthoppers has been observed on light trap catches in Thailand for the last 10 years, this country also practiced the use of insecticides for planthopper management. Among the insecticides that are common in Thailand, the brown planthopper was found to be resistant to imidacloprid in 2003 (Harris 2006). In a survey conducted by Meenakanit et al (in 1997), most of the women farmers that they interviewed used pesticides for brown planthopper and applied their first spray within the first 30 days after planting. Pesticide application frequencies ranged from 1 to 10 per season, with 1–3 times as the most common. Furthermore, approximately one-half of Thai farmers apply higher than recommended concentrations, do not pay attention to labels, wear no protective clothing, and do not observe recommended intervals between spraying and harvest (Jungbluth 1996). Although there are no direct subsidies on pesticides in Thailand, several factors encourage pesticide use: low import taxes have helped keep prices down, there is little independent information or training and the extension service focuses primarily on pesticide-based pest management, and the government keeps a budget for emergency outbreaks of pests, generally using pesticides to contain the problem (Jungbluth 1996).

In Vietnam, the population of brown planthoppers declined over the last 10 years mainly because of unfavorable weather conditions such as typhoons and floods in September and October in 1999-2003 and the diversification of the genetic background for resistance to BPH in rice varieties (Chau 2007). Despite the low population density of the brown planthopper, its hopper-burn damage increased in 2006 and 2007. This may have been due to abnormal weather in the Mekong Delta; a simple gene source of resistance to BPH; the development of BPH on susceptible aromatic rice varieties; farmers kept the habit of high seed rates, more nitrogen application, and misuse of insecticides; and the development of BPH virulence. It was also observed that several insecticides, such as imidacloprid and fenobucarb, have developed resistance to brown planthopper (Chau 2007). In 2005-06, BPH and the resulting ragged stunt rice disease damaged four consecutive rice crops (Vietnam News 2006). The disease spread over 485,000 hectares of rice fields, resulting in the loss of 828,000 tons of rice. Funds for pesticides had been provided to farmers to counteract this menace.

In general, the brown planthopper and whitebacked planthopper are secondary pests brought about by an overuse of insecticides. Many research studies were conducted to prove this claim. For example, in an experiment in Thailand, rice plots treated with insecticide supported high planthopper populations because of their eggs and nymphs, whereas planthopper populations in plots not receiving an insecticide treatment did not increase (Kenmore 1991). Likewise, in a study by Heong and Schoenly (1998), insecticides that had been tested in field plot experiments favored the development of planthoppers and destroyed natural enemies. When brown planthoppers were introduced to treated resistant rice varieties, the resistant varieties lost their effectiveness, causing a density increase in the BPH population (Gallagher et al

1994). On some occasions when insecticides were suddenly stopped, rice crops suffered high BPH attacks mainly from recruitments from neighboring fields (Way and Heong 1994). In a study on some organophosphate and pyrethroid pesticides, these caused increased fecundity of BPH, thus further increasing the probability of outbreak (Heinrichs and Mochida 1984). The indiscriminate use of insecticides not only caused outbreaks of planthoppers but also killed the natural enemies present in the rice field (Kenmore et al 1984). When broad-spectrum pesticides are applied, natural enemies can be selectively destroyed, allowing populations of *N. lugens* to increase 1,000 times compared with densities when pesticides are not used (Kenmore 1980, Ooi 1988). This promoted resurgence of the insect pest (Heinrichs and Mochida 1984). Brown planthoppers that were reared on high-nitrogen applications have significantly higher ecological fitness (Cook and Denno 1994). Furthermore, most of the fitness variables of BPH increased in successive generations in high-nitrogen regimes (Lu et al 2004). In the 1970s and '80s, nitrogen fertilization was implicated as a cause of BPH outbreaks and a threat to the rice industry (Dyck et al 1979, Heinrichs and Mochida 1984). This implication was based on experiments in greenhouses without natural enemies or in fields where insecticides were heavily used.

Conclusions

The brown planthopper and the whitebacked planthopper are problem pests in China and Vietnam, two of the Asian countries involved in this report. Continuous research studies are being conducted to overcome the problems that they cause to rice production. The rice planthopper problem in these two Asian countries is due to their continuous use of insecticides, their most common measure for planthopper management. When the use of insecticides declines, problems in rice fields brought about by planthoppers will decline. Using insecticides judiciously will lead to the conservation of natural enemies that will help check not only the population increase of planthoppers but other insect pests as well. It will also solve the problem of insecticide resistance, which will prevent secondary pest outbreaks and resurgence of targeted insect pests.

China and Vietnam, along with the other Asian countries, focus their research on insecticide evaluation, screening of varieties, and some laboratory studies. Limited research is being done on developing field resistance and ecology. Considering the known harmful effect of insecticides, Asian countries should identify other research studies and issues related to the management of planthoppers.

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Notes

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