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Rapid assessments of the rice brown planthopper (*Nilaparvata lugens* Stål) outbreak in Semarang District, Central Java: Effects of farmers' low KAP

Belajar dari kajian cepat ledakan wereng coklat (*Nilaparvata lugens* Stål) di Kabupaten Semarang, Jawa Tengah: Pengaruh dari rendahnya PST petani

Hermanu Triwidodo[1], Bonjok Istiaji[1*], Nurul Farida Efriani[1], Lilik Retnowati[2], Niky Elfa Amanatillah[1]

[1]Departemen Proteksi Tanaman, Fakultas Pertanian, IPB University
Jalan Kamper, Kampus IPB Dramaga, Bogor 16680, Indonesia
[2]Direktorat Perlindungan Tanaman Pangan
Jalan AUP Pasar Minggu No.3, Jakarta 12520, Indonesia

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ABSTRACT

Rapid assessments on the outbreak of rice brown planthoppers (BPH) (*Nilaparvata lugens* Stål) were conducted to investigate the status of BPH populations and the causative factors behind the outbreak. These assessments served as the basis for developing a proper action program. The assessments took place in Banyubiru Sub-District, Semarang District covering four villages (Kebondowo, Rowoboni, Tegaron, Kebumen) in December 2013. We analyzed BPH data, along with information about farmers' practices in managing pests collected through interviews conducted in January 2018 in Indramayu. Additionally, we examined data on the number of BPH-infested areas in Java from 2010 to 2020 and the stock of insecticides in Java in 2021. Simple statistical analyses were carried out. The BPH population had spread throughout Banyubiru and was present in all sampled plots. The average number of BPH eggs ranged from 115.25 to 379.65 per rice hill, while the BPH nymphs and imagoes ranged from 3.42 to 11.87 per rice hill. The relatively low nymphs to imagoes ratio might be influenced by the high BPH predator populations, which ranged from three to six individuals per rice hill. Suspected causes of BPH resistance and resurgence included the application of banned and improper insecticides, as well as the repeated use of the same insecticide active ingredients for an extended period. It is recommended to discontinue the mass spraying of insecticides to prevent further plant damage. In 2022, the Pest Control Movement has suggested replacing chemical insecticides with biological or natural pesticides. Intensive extension programs are strongly needed.

Key words: neonicotinoid, planthopper outbreaks, pyrethroid, rapid assessment, resurgence

ABSTRAK

Kajian cepat ledakan wereng batang coklat (WBC) (*Nilaparvata lugens* Stål) dilakukan untuk mempelajari status populasi WBC dan faktor penyebab ledakan sebagai dasar untuk mengembangkan program aksi yang tepat. Kajian ini dilakukan di Kecamatan Banyubiru, Semarang, Jawa Tengah, di 4 desa (Kebondowo, Rowoboni, Tegaron, dan Kebumen) pada Desember 2013. Data kajian ledakan WBC dianalis dengan informasi tentang praktik pengendalian hama oleh petani melalui wawancara (Januari 2018 di Kabupaten Indramayu), data luas wilayah yang terserang BPH di Jawa (2010–2020),

*Penulis korespondensi: Bonjok Istiaji. Departemen Proteksi Tanaman, Fakultas Pertanian, IPB University
Jalan Kamper, Kampus IPB Dramaga, Bogor 16680, Indonesia, Tel/Faks: 0251-8629364 / 0251-8629362, Email: bistiaji@apps.ipb.ac.id

dan data stok insektisida di Jawa (2021), kemudian dilakukan analisis statistik sederhana. Populasi WBC tersebar di Banyubiru dan dapat ditemukan di seluruh petak sampel Desa Kebondowo, Rowoboni, Tegaron, dan Kebumen. Rata-rata jumlah telur WBC berkisar 115,25 sampai 379,65 per rumpun padi, sedangkan nimfa-imago WBC berkisar 3,42 sampai 11,87 per rumpun padi. Rendahnya populasi imago-nimfa kemungkinan dipengaruhi oleh tingginya populasi predator WBC yang berkisar tiga hingga enam individu per rumpun padi. Penggunaan insektisida yang dilarang dan tidak tepat, serta penggunaan berulang bahan aktif insektisida yang sama dalam waktu relatif lama diduga sebagai penyebab resistensi dan resurjensi WBC. Program penyemprotan massal insektisida direkomendasikan untuk dihentikan untuk mencegah kerusakan tanaman yang semakin parah. Saat ini di tahun 2022 Gerakan Pengendalian (Gerdal) OPT dengan menggunakan insektisida kimia telah disarankan diganti dengan Gerdal dengan menggunakan pestisida biologi atau alami. Program penyuluhan intensif sangat dibutuhkan dalam hal ini.

Kata kunci: kajian cepat, ledakan wereng, neonikotinoid, piretroid, resurgensi

INTRODUCTION

The Indonesian rice planting season in 2013 occurred during a wet dry season (Yulihastin et al. 2021), characterized by an unusually high number of rainy days and above-average rainfall, exceeding the typical condition of a dry season. The availability of water encouraged farmers to continuously plant rice throughout the year, resulting in staggered rice plantations that were not paused. The situation made the rice agroecosystem more vulnerable to pest attacks (Baehaki & Mejaya 2014). The buildups of pest infestations were reported in most rice central production areas of Indonesia. In early November 2013, there was a report that planthoppers, predominantly the white-backed planthopper (WBP) (*Sogatella furcifera* Horvarth) (Hemiptera: Delphacidae), had infested 125 hectares out of 759 hectares of rice plantations in Banyubiru Sub-district, Semarang District, Central Java. The local agricultural authority responded promptly by distributing insecticides and mobilizing farmers to conduct weekly mass spraying to prevent the infestation from spreading. However, despite efforts to control the WBP infestation, plant damage continued to worsen. By the end of November, 40% of the rice plantation areas shown early symptoms of planthopper burns, and the planthoppers population had become dominated by rice brown planthoppers (BPH) (*Nilaparvata lugens* Stal) (Hemiptera: Delphacidae).

BPH is one of the most important pests in rice plantations. Besides its role as a pest itself, BPH is also the vector of the rice-ragged stunt virus. BPH attacks can significantly decrease rice production, both qualitatively and quantitatively. Outbreaks of this pest need to be prevented to ensure an adequate rice supply. Studies on BPH in Indonesia have covered various topics due to the importance of this pest, including research on resistance varieties (Dianawati & Sujitno 2015; Iswanto et al. 2015), natural enemies (Gunawan et al. 2015; Sianipar et al. 2017), biocontrol agents (Aristyawan et al. 2020; Kuswoyo 2022), and more. Unfortunately, detailed and specific studies on BPH outbreaks in Indonesia remain limited.

BPH outbreaks in Central Java in 2013 resulted in significant yield losses (Triwidodo 2020), highlighting the need to analyze this issue to prevent similar occurrences. We hypothesized that these outbreaks were influenced by the pesticides used by farmers. Knowledge, attitude, and practice (KAP) among farmers, particularly regarding pesticide use, are suspected to be linked with pest infestation. The Plant Clinic of The Department of Plant Protection, IPB University responded promptly by conducting rapid assessments of the BPH outbreaks in the Banyubiru Sub-district. The purpose of this study is to investigate the status of BPH populations and the causative factors behind the outbreaks, forming the basis for developing a proper action program. This paper provides and documents the processes, results, and recommendations of the rapid assessments.

MATERIALS AND METHODS

Brown plant hopper and its predator population

Rapid assessments of BPH outbreaks were conducted over 10 days period in December

2013 in Banyubiru Sub-district, Semarang District, Central Java. The study assessed the current status of the BPH population across four villages: Kebondowo, Rowoboni, Tegaron, and Kebumen. To select the rice plots for examination, we employed a systematic sampling approach with random start procedures along a transect line in the largest rice field, ensuring a 15 plots distances between selected plots. Each rice plots was assessed within a distance range of 17 cm x 17 cm to 22 cm x 22 cm for each plants. In each plot, a cluster of ten rice hills was randomly selected to observe the number of BPH nymphs, imagoes, and predators. Furthermore, the count of BPH eggs per rice hill was conducted by dissecting one randomly selected rice hill out of the ten hills. The decision to use a small sample size was influenced by the homogenous distribution of BPH populations within plots under outbreak conditions, as well as time constraints for assessments.

Therefore, we randomly selected paddies with severe BPH damage resulting in hopper burn (6 plots), moderate BPH damage (5 plots), and healthy crops (5 plots) in the largest rice field near Rowoboni, Tegaron, and Kebumen villages. We assessed the populations of BPH eggs, nymphs, and imagoes in the selected plot and conducted interviews with the farmers managing these plots. The farmers were questioned about the frequency of pesticide applications, the type of pesticides used, and other control measures, as we described below.

Pesticide uses practice

The BPH outbreaks in Central Java in 2013 were attributed to improper pesticides usage by farmers, triggered by extensive insecticide distribution and the mobilization of farmers for weekly mass spraying. Data on farmers' pest management practices were collected through interviews. Between December 2017 and January 2018, we gathered information from 46 rice farmer respondents, including 36 conventional farmers and 10 employing the integrated pest management (IPM) method. Structured questionnaires were directly administered to the respondents, encompassing questions related to pesticide usage patterns. The data were collected from Widasari Sub District and Lelea Sub District, Indramayu District, West Java.

We randomly selected paddies with varying levels of health and damage caused by BPH, including moderate and severe hopper burn damages, within the same rice fields. The farmer respondents responsible for managing the selected paddies were interviewed regarding the number of pesticide applications and the specific pesticides used. We also conducted BPH population observations in these paddies, utilizing the same sampling procedures as previously described. Qualitative soil tests were performed for the paddies using the procedures and Paddy Soil Test Kits developed by The Soil Research Institute, Indonesian Agency for Agriculture Research and Development (ISRI 2005).

Brown planthopper infested areas and stocks of insecticides in Java Island

Secondary data concerning the number of BPH-infested areas in three provinces of Java Island from 2010 to 2020, were obtained from The Directorate of Food Crop Protection. Additionally, secondary data on the stock of insecticides in three provinces of Java Island as of June 2021 were collected from The Center for Plant Variety and Agricultural Licensing Protection.

Data analysis

We performed simple statistical analysis using descriptive methods with the SAS System for Windows 9.0 software to analyze the collected data.

RESULTS

Brown plant hopper and its predator population

The appearance of rice fields in the study areas was devastating, resembling typical scenes of BPH outbreak areas (Figure 1). Paddies with hopperburn spots were scattered throughout rice plantations in the Banyubiru Sub-district, including the villages of Kebondowo, Rowoboni, Tegaron, and Kebumen. Most of the rice plantations were in reproductive stages, ranging from 10 to 14 weeks after transplanting. Detailed investigations of the affected spots, achieved by dissecting rice tillers and examining rice stems, confirmed that the damages were indeed caused by BPH (Figure 2).

BPH populations were discovered in all sampled plots across Kebondowo, Rowoboni,

Figure 1. Typical views of BPH infested rice field at Banyubiru Sub-district, Semarang District, Central Java, December 2013.

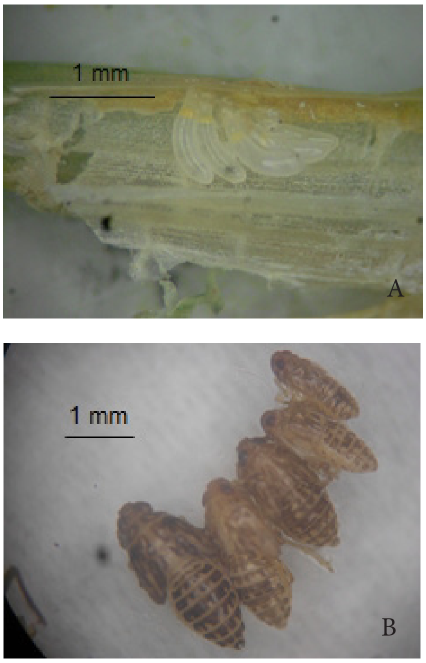

Figure 2. BPH eggs (A) and nymphs (B) collected from BPH infested area at Banyubiru Sub-district, Semarang District, Central Java, December 2013.

Tegaron, and Kebumen Villages (Table 1), indicating widespread BPH infestation across the rice growing areas of the Banyubiru Sub-district. The age structure of the BPH population was predominantly at the egg stage. The average number of BPH eggs per rice hill in Kebondowo, Rowoboni, Tegaron, and Kebumen were 379.65, 256.10, 131.70, and 115.25, respectively. However, there were no significant differences in the BPH egg populations among villages. The populations of BPH nymphs and imagoes were relatively low. The number of BPH nymphs and imagoes per rice hill was lowest in Kebondowo (3.42), significantly differing from the highest number observed in Kebumen (11.87). The numbers in Rowoboni (6.96) and Tegaron (7.41) were comparable to both Kebondowo and Kebumen. BPH predator populations were quite high, ranging from approximately three to six individuals per rice hill. The highest predator populations were observed in Tegaron and Kebumen. The abundance of predators likely played a crucial roles in keeping BPH nymphs and imagoes in check, despite the high BPH egg populations. During the observations, five species of predators were found: *Microvellia* sp., *Cyrtorhinus* sp., *Paederus* sp., *Ophionea* sp., and *Synharmonia* sp. No spiders were found during the observations.

The extent of BPH infestations and predator coverage could be roughly estimated by examining the percentages of sampled plots where BPHs and predators were found (Figure 3). BPH nymphs, imagoes, and predators were present in all sampled plots of all villages; however, BPH eggs were not found in all sampled plots. The percentages of sampled plots with BPH eggs in Kebondowo, Rowoboni, Tegaron, and Kebumen

Table 1. BPH population and its predator at BPH infested area at Banyubiru Sub-district, Semarang District, Central Java, December 2013

Villages	Number per hill (average ± standard error)*			
	n	BPH eggs	BPH nymphs & imagoes	Predators
Kebondowo	10	379.65 ± 18.23 a	3.42 ± 1.05 a	2.82 ± 0.28 a
Rowoboni	10	256.10 ± 79.95 a	6.96 ± 0.72 ab	3.29 ± 0.39 a
Tegaron	10	131.70 ± 90.32 a	7.41 ± 1.98 ab	5.35 ± 0.80 b
Kebumen	10	115.25 ± 18.37 a	11.87 ± 2.95 b	4.04 ± 0.37 ab

*The numbers of the same column followed by the same letters are not significantly differenttased on the Duncan Multiple Range Test ($\alpha = 0.05$).

were 70%, 80%, 50%, and 100%, respectively. The information presented in Table 1 and Figure 3 suggests Kebumen, Rowoboni, Kebondowo, and Teragon vullages would experience the highest to the lowest degree of BPH threats, respectively.

All respondents indicated that the primary method of pest control was pesticide application or spraying, without considering alternative pest control measures. They were heavily reliant on pesticides rice pest management. We summarized the BPH populations and the number of pesticide sprays in healthy, moderately BPH-damaged, and severely hopper-burned BPH-damaged rice plots (Table 2). There were no significant differences in the number of BPH eggs per rice hill among rice plots with different levels of BPH damage. However, the number of BPH nymphs and adults per rice hill significantly varied among plots with different levels of BPH damage. The highest population was found in the severely-hopper-burned BPH-damaged plots (averaging 46.50 individuals per rice hill), while the lowest population was found in the healthy rice plots (averaging 7.80 individuals per rice hill). The moderately BPH-damaged plots had an average population of 20.40 individuals per rice hill. These population differences corresponded with the severity of the damages.

The number of BPH nymphs and adults per rice hill differed among plots with varying levels of BPH damage, even when the number of BPH eggs per hill was the same. This suggests varying intensities of mortality factors that hindered the development of BPH eggs into nymphs and indicated predation on BPH nymphs/adults. In a healthy environment, the BPH population could not thrive due to the presence of numerous natural population control factors, such as egg parasitoids and predators. If these natural control factors were absent, the BPH population could grow to unchecked. In most cases, indiscriminate use of pesticides was the cause of the destruction of natural controls. These phenomena were likely to occur in the studied plots in the Banyubiru Sub-

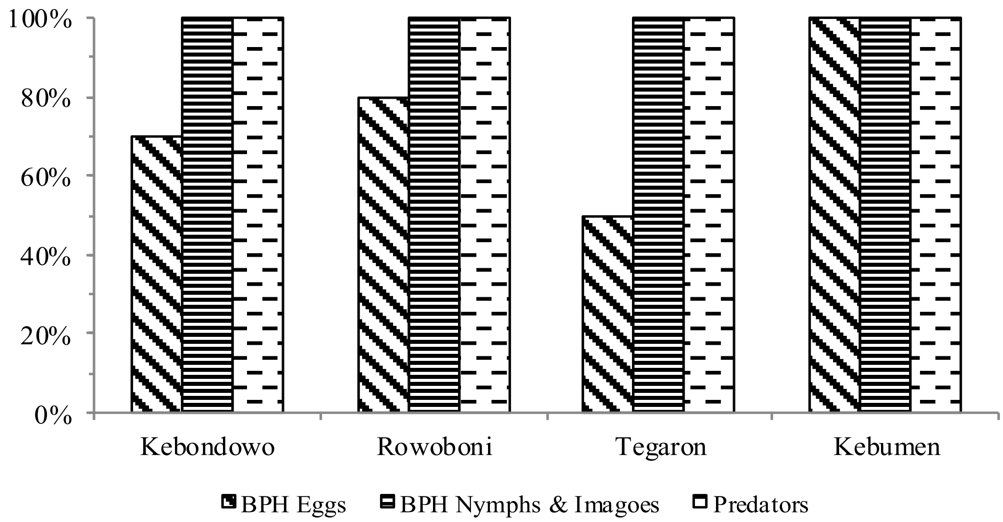

Figure 3. Percentages of sampled plots where BPH eggs, BPH nymphs and imagoes, and predators were found at four villages in Banyubiru Sub-district, Semarang District, Central Java, December 2013.

Table 2. BPH population and the number of sprays in rice paddies of difference levels of damages caused by BPH at Banyubiru Sub-district, Semarang District, Central Java, December 2013

Plant damages	n	BPH per hill (average ± standard error)		Number of sprays (average ± standard error)
		Eggs	Nymphs/imagoes	
Healthy	5	209.13 ± 170.32 a	7.80 ± 1.46 a	2.00 ± 1.05 a
Moderate	5	150.50 ± 41.96 a	20.40 ± 2.58 ab	4.80 ± 2.20 ab
Severe - Hopperburn	6	145.22 ± 34.65 a	46.50 ± 14.13 b	7.50 ± 1.57 b

The numbers of the same column followed by the same letters are not significantly different based on the Duncan Multiple Range Test (α = 0.05).

district. Healthy rice plots had experienced on average of 2 pesticide sprays (ranging from 0 to 5 sprays); moderately BPH-damaged plots had experienced an average of 4.80 sprays (ranging from 1 to 13 sprays); while severely hopper-burned BPH-damaged plots had experienced an average of 7.50 sprays (ranging from 2 to 12 sprays). More frequent pesticides sprayed disrupted natural controls, accelerated BPH population growth, and led to more severe BPH damage. It can be concluded that frequent pesticide sprays did not prevent or reduce BPH attacks; on the contrary, they might have exacerbated severe BPP attacks.

Pesticide uses practice

All respondents expressed their eagerness to spray pesticides when their rice fields faced pest threats. However, most of the time, they were unable to do so due to a lack of funds to purchase pesticides. These situations were particularly faced by respondents with healthy paddy plots, which prevented them from carrying out pesticide sprays. Therefore, the limited number of sprays did not result from a good understanding of the adverse effects of pesticides on BPH natural enemies, but rather due to financial constraints. Similar responses were obtained regarding the use of pesticide mixtures for spraying. Out of 79 spraying events conducted by all respondents, 32 events (41%) involved the use of a single pesticide, 34 events (43%) used mixtures of two pesticides, 12 events (15%) used mixtures of three pesticides, and one event (1%) employed a mixture of four pesticides (Figure 4). The practices of using a single pesticide and mixtures of two pesticides were not driven by awareness of potential adverse environmental effects but rather by the inability to afford more pesticides.

We summarized the frequencies of pesticide trade names used by farmer respondents in 79 spraying events (Table 3). Under pests pressures and limited purchasing powers, some farmers resorted to using non-pesticide substances, such as salt (in approximately 4% of spraying events), or non-agriculture pesticides like household pesticides like Baygon (with active ingredients cypermethrin, imiprothrin, prallethrin, transflurin; in about 6% of spraying events) and magic chalk (with active ingredients deltamethrin; one spraying event). Additionally, some farmers used mosquito repellent lotions containing diethyltoluamide (in about 6% of spraying events). There were two events that involved the use of a commercial bioinsecticide, Primasid (with active ingredients *Trichoderma* sp. and *Gliocladium* sp.), and one event that used a homemade botanical insecticide from the Gadung plant (*Dioscorea hispida*). Most of the other agricultural pesticides used by the respondents were common and readily available in agricultural stores or kiosks in the Banyubiru Sub-district. The choices of the pesticides were influenced by their affordability and recommendations from kiosk salespersons. The respondents had not received proper guidance or recommendations from official agricultural extension workers. It should be noted that the respondents, and likely most of the farmers in the Banyubiru Sub-district, had limited knowledge of the pesticides used in rice cultivation. Consequently, most of the pesticides were those that might promote BPH resurgence and had been banned for use on rice by Indonesian authorities. The three most frequently used pesticide active ingredients were pyrethroid (38 spray events; 48%), neonicotinoid (28 spray events; 35%), and neristoxin (18 spray events; 23%) (Table 3).

We summarized the results of qualitative soil tests conducted using procedures and kits developed by The Indonesian Soil Research Institute (Table 4). The condition of respondents' paddy soils may reflect the overall conditions of paddies in the Banyubiru Sub-district. The soil

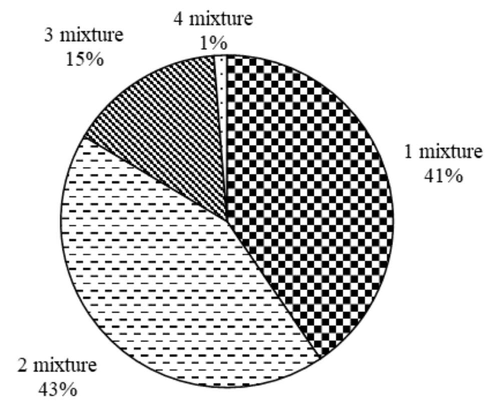

Figure 4. The number of pesticides mixtures per application practiced by rice farmers during the first rice planting season (October to December 2013) at Banyubiru Sub district, Semarang District, Central Java (n = 79 pesticides sprays).

acidity levels were moderately to slightly acidic (pH 5−6), which is suitable for rice cultivation. However, the nutrient statuses of the soil were sub-optimal, except for nitrogen, which was categorized as high. Potassium and phosphorous levels were mostly low to medium.

To provide a more recent comparison, a study conducted from 2017 to 2018 in the Indramayu District aimed to understand pesticide use patterns in Java. The most frequently used active ingredient was abamectin from the avermectin group, accounting for 26.4% among conventional farmers, and 8.5% among IPM farmers. Another commonly used active ingredient in pesticides was dimehypo (Table 5). These active ingredients are still readily available in agricultural kiosks and accessible to farmers.

Regarding pesticide use by rice farmers in Indramayu, our results found that in Indramayu in 2017 (Figure 5), 70% reported following the instruction on the label, while 30% of farmers did not follow the instructions on the label, and some applied pesticides that were not suitable for pests and diseases in rice plants. They assumed that the pests they encountered in the rice fields were similar to those described on the label. Consequently, they used pesticides intended for other crops such as shallot, tomatoes, soybeans, etc.

Brown planthopper-infested areas

The number of BPH-infested areas in three provinces of Java Island over the past ten years, from 2010 to 2020, exhibited fluctuations. The highest infestation occurred in East Java in 2011, with the number of infested areas reaching 146.548 hectares. In the same year, the infestation area in West Java was relatively low, covering only 6.432 ha. Subsequently, from 2012 onwards, the infested areas in all three provinces remained below 60.000 ha. Interestingly, during that decade, these three provinces experienced four peaks or highest points in the number of BPH-infested areas (Figure 6).

Stocks of insecticides on Java Island

Table 6 illustrates that the stock of rice insecticides, especially insecticide used for controlling the brown planthopper (BPH), rice stem borer (RSB), and BPH & RSB, was substantial in the three provinces of Java, totaling 168.631,20 kilograms as of June 2021. Among these types of insecticides, Central Java had the highest stock, with 88.435,00 kilograms in the same month.

Table 3. Pesticides used by rice farmers during the first rice planting season (October to December 2013) at Banyubiru Sub district, Semarang District, Central Java (n = 79 pesticides sprays)

No.	Pesticides trademark	Active ingredients	Frequencies	Percentages
1.	Decis	Deltamethrin	22	27,85
2.	Manuver	Dimehypo	18	22,78
3.	Starvidor	Imidacloprid	15	18,99
4.	Darmabas	BPMC	13	16,46
5.	Matador	Lamda Cyhalothrin	11	13,92
6.	Oshin	Dinotefuran	10	12,66
7.	Dorsa	Imidacloprid, Lamda Cyhalothrin	9	11,39
8.	Baygon	Cypermethrin, Imiprothrin, Prallethrin, Transflurin	5	6,33
9.	Lavender and Autan (Mosquito repellent)	Diethyltoluamide	5	6,33
10.	Diazinon	Diazinon	4	5,06
11.	Confidor	Imidacloprid	4	5,06
12.	Opera	Cypermethrin	4	5,06
13.	Lanatte	Metomil	4	5,06
14.	Garam (Salt)	NaCl	3	3,80
15.	Primasid	Trichoderma sp., Gliocladium sp.	2	2,53
16.	Kapur ajaib (Magic chalk)	Deltamethrin	1	1,27
17.	Gadung plant	Saponin	1	1,27

Table 4. Soil condition of rice paddies owned by farmer respondents at Banyubiru Sub-district, Semarang District, Central Java, December 2013

No.	Farmers	Village	Plant damage	pH	N	K	P	Organic matter
1.	Abidin	Kebumen	Healthy	5	High	Low	Low	Low
2.	Junaedi	Rowoboni	Healthy	5	High	Medium	Low	Low
3.	Warno	Rowoboni	Healthy	5	High	Medium	Low	Low
4.	Amin	Tegaron	Healthy	5	High	High	Low	Low
5.	Hariono	Tegaron	Healthy	6	High	High	Medium	Low
6.	Arif	Kebumen	Moderate	5	High	Medium	Low	Low
7.	Suparni	Kebumen	Moderate	5	High	Medium	Medium	Low
8.	Ahmadi	Rowoboni	Moderate	5	High	Medium	Low	Low
9.	Jaelani	Rowoboni	Moderate	5	High	Medium	Medium	Low
10.	Mahdi	Rowoboni	Moderate	6	High	Medium	Medium	Low
11.	Jaelani	Kebumen	Severe	5	High	Medium	Medium	Low
12.	Lasim	Rowoboni	Severe	5	High	Low	Low	Low
13.	Sunardi	Tegaron	Severe	4	High	Medium	Low	Low
14.	Ngatijan	Tegaron	Severe	5	High	Low	Low	Low
15.	Usup	Kebumen	hopperburn	5	High	Medium	Low	Low
16.	Salimin	Kebumen	hopperburn	5	High	Medium	Low	Low

Table 5. Active ingredients of pesticides used by rice farmers in Indramayu

Active ingredient	Group of active ingedients	Number of trandemarks	Percentage	
			Conventional	IPM
Abamectin	Avermectin	3	26.4	8.5
Acephate	Organophosphate	1	0.5	0
Buprofezin	Thiadiazine	1	1.4	5.6
Dimehypo	Neristoxin	5	11.4	19.7
Dinotefuran	Thiosulfonate	1	1.6	0
Emamectin benzoate	Avermectin	1	0.2	0
Etophenprox	Diphenyl	1	1.4	5.6
Fipronil	Phenyl pyrazole	1	5.7	4.2
Imidacloprid	Neonikotinoids	1	5.9	5.6
Carbofuran	Carbamate	2	0.9	0
Chlorantraniliprole	Diamide	1	4.8	0
Chlorpyrifos	Organophosphates, Pyridine	2	1.1	5.6
Chlorpyrifos, Cypermethrin	Organophosphates, Pyridine	2	3.4	0
Nitenpiram	Neonikotinoids	1	6.4	0
Pymetrozine	Triazine	1	8.9	9.9
Profenophos	Neristoxin	1	1.4	0
Pyrethrum	Pyrethroids	1	1.1	0

DISCUSSION

Brown plant hopper and its predator population

BPH has long been recognized as a pest associated with the green revolution. Initially, BPH was rarely encountered in the rice ecosystem due to the presence of various natural mortality factors, such as predators and parasitoids, which prevented its population from thriving. However, BPH has evolved into a major rice pest with the adoption of scheduled or regular broad-spectrum insecticides applications. The indiscriminate use of insecticides has had a more detrimental impact on natural mortality factors than on the BPH populations itself, which has relatively easily developed resistance to these insecticides. Consequently, the emergence of insecticide-resistant BPH populations, coupled with the absence of natural enemies, has led to an exponential growth in BPH population, resulting in pests outbreak situations. These phenomena are referred to as an insecticide-induced BPH resurgence (Reissig et al. 1982; Heong et al. 2013). Comparable phenomena may have contributed to the BPH outbreak process in the Banyubiru Sub-district. The escalation of BPH-damaged areas followed the mass pesticide spraying program designed to combat WBP infestations. It can be surmised that

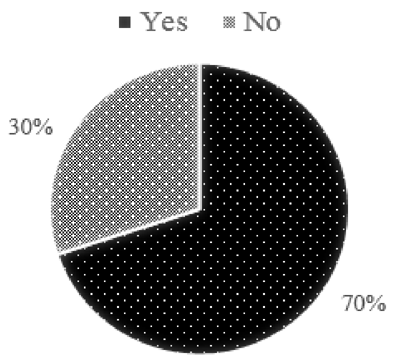

Figure 5. Percentage of pesticide uses suitability in rice plants in Indramayu.

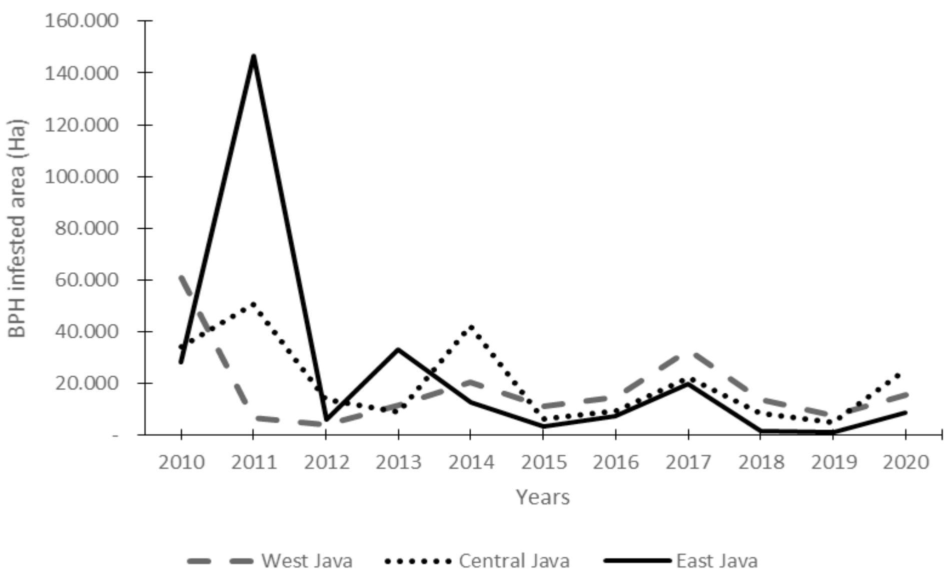

Figure 6. The number of BPH infested areas in three provinces of Java Island, 2010−2020. Source: Directorate of Food Crop Protection, Indonesian Ministry of Agriculture, Jakarta.

Table 6. Stocks of brown planthopper (BPH), rice stem borer (RSB), and BPH & RSB insecticide in three provinces of Java Island, June 2021

Province	Stock of insecticide (kg)			
	BPH insecticide	RSB insecticide	BPH and RSB insecticide	Total
West Java	18.717,00	1.840,00	36.577,60	57.134,60
Central Java	40.377,00	21.181,00	26.877,00	88.435,00
East Java	17.122,90	1.887,80	4.050,90	23.061,60
Total				168.631,20

Source: The Center for Plant Variety and Agricultural Licensing Protection, Indonesian Ministry of Agriculture, Jakarta.

this spraying program had little to no effect on the BPH population but had a detrimental impact on natural enemies. Table 2 provides evidences that increased pesticide application correlated with higher observed BPH populations observed and the more severe resulting plant damage.

Pesticide use practices

It was suspected that the local BPH population had already developed resistance to insecticides. Respondent farmers pointed out that for the past few years, three insecticide products or trade names containing active ingredients such as deltamethrin, dimehypo, and imidacloprid had dominated insecticide usage (Table 3). Furthermore, the number of insecticide sprays could reach up to 13 sprays per rice growing season. These conditions might have exerted intensive selection pressures, accelerating the BPH population's resistance to pesticides with those active ingredients and potentially promoting cross-resistance to other pesticides in the same classes. The development of BPH resistance to deltamethrin and imidacloprid had been reported in various rice-growing areas, including Java, Indonesia (Chelliah & Heinrichs 1980; Reissig et al. 1982; Nagata 2002; Gorman et al. 2008; Tan 2009; Norton et al. 2010; Sutrisno 2014). Furthermore, it had been reported that the use of pyrethroids, such as deltamethrin, and neonicotinoids, such as imidacloprid could increase the nutritional value of rice plants. This enhancement resulted in increased BPH feeding rates, fecundity, and longevity, and could directly stimulate BPH reproductive capacity (Ratna et al. 2009).

Twopaddy plots with healthy crops were found to have high potassium levels. The Indonesian Soil Research Institute recommended applying 92 kg N/ha of fertilizer to paddy with high N category, 100 kg SP36/ha for low P Category, 75 kg SP36/ha for medium P category, 100 kg KCl/ha for low K category and 50 kg KCl/ha for medium K category (ISRI 2005). The soil organic matter content was low, i.e. less than 1%. For optimal rice growth, it is recommended to have at least 2.5% soil organic matter (Dobermann & Fairhurst 2002).

The soil conditions in Banyubiru paddy fields were typical of almost all rice-growing areas in Java. They were moderately to slightly acidic, had low organic matter, high nitrogen, low phosphorous, and low potassium levels. The use of N fertilizer steadily increased every year to double the recommended dosage of 200kg urea/ha. Conversely, P and K fertilizers were almost neglected. This occurred partly because N fertilizers were easier to obtain, more affordable, and provided a quicker crop response for farmers. Excessive N application increased soluble proteins and decreased silicon contents in rice plants, making them more susceptible to BPH feeding habits and pests susceptibility (Rashid et al. 2016). The practices of removing rice straw from paddies or burning rice straws after harvest led to nutrient loss, significantly reducing organic matter contents. One ton rice straw contained 5–8 kg N, 1.6–2.7 kg P_2O_5, 14–20 kg K_2O, 0.5–1.0 kg S and 40–70 kg Si (Dobermann & Fairhurst 2002). An estimated 8 tons of rice straws per hectare of rice fields could be present. Maintaining the rice straw in the rice fields could reduce the need for additional K fertilizer 50 kg KCl/ha (ISRI 2005). Adequate K and Si contents in rice plants made the plant more resilient to BPH attacks (Ma 2004). These deficient soil fertility conditions likely resulted in imperfect rice plant growth, increasing vulnerability to pest attacks.

The rapid assessments also revealed concerning information about the knowledge, attitudes, and practices (KAP) of the interviewed respondents in managing rice pest problems. Integrated pest management (IPM) was officially as the approach to pest control by the Indonesian Government and has been extensively promoted since the early 1990s. The institutionalized of IPM among rice farmers has been carried out intensively through activities like Farmer Field Schools, Action Research Facilities, and Regular Extension Programs. Surprisingly, it was found that respondents' KAP remained largely unchanged from the KAP of rice farmers described by Kartaatmadja et al. (1997) before the implementation of the IPM program. They predominant belief was that applying pesticides was the sole method of pest control. They relied on advice from salespersons and kiosks when selecting pesticides, resulting in the use of banned insecticides and pesticides discouraged for rice cultivation due to their potential to promote BPH resurgence. These findings may not fully represent the KAP of all Banyubiru farmers but should not be disregarded. Serious efforts are needed to reevaluate farmer's IPM KAP, especially concerning the judicious use of pesticides. Without such efforts, it would be impossible to prevent future BPH outbreaks.

The rapid assessments revealed that the BPH population had spread throughout the rice-growing area of the Banyubiru Sub-district. BPH populations were found in all of the sampled plots of Kebondowo, Rowoboni, Tegaron, and Kebumen Villages. The BPH populations were dominated by egg stage, with an average number of 379.65, 256.10, 131.70, and 115.25 per rice hill in Kebondowo, Rowoboni, Tegaron, and Kebumen Villages, respectively. These high BPH egg populations could develop into nymphs and cause serious damage to rice crops. Fortunately, relatively high BPH predator populations were found at all sampled plots, ranging from about three to six individuals per rice hill. The presence of these natural enemies prevented the BPH population from building up. Any actions, especially insecticide applications, that might harm these natural enemies should be avoided.

In response to the issues we uncovered from these results, the Directorate of Food Crop Protection, Indonesia incorporated our IPM-based recommendations into national programs. These programs encompass the application of IPM, climate change effect management (to mitigate outbreaks caused by climate factors), multiplication of natural enemies and refugia plantations, biological control service posts, support for owl houses, and technical coaching programs. These initiaitives have been implemented annually since 2009. They encompass principal components of IPM: healthy plant cultivation, frequent monitoring, the use of natural enemies, and the empowerment of farmers as experts. When all of these components are diligently applied, explosive BPH attacks can be prevented.

According to Bottrell & Schoenly (2018), the key to adopting IPM adoption is to persuade farmers to integrate non-chemical alternatives as primary management components and to use pesticides judiciously, resorting to them only after non-chemical methods have failed to manage pests effectively. Planting flowering plants as refugia is a technical cultural method for reducing BPH populations in fields. Plantating refugia plants can indirectly reduce pests by providing shelter and food for natural enemies. A study conducted by Ali et al. (2019) demonstrated a significant increase in the rates of predators, parasitoids, and parasitism in ecoengineering rice field plots where nectar-rich flowering plants were planted, compared to insecticide-treated plots. This study also highlighted that the application of the IPM system through habitat manipulation could maintain yields.

Brown planthopper-infested areas

The application of the IPM system has been successful in reducing infested areas and supporting higher yields, as evidenced by the number of BPH-infested areas in three provinces of Java Island (Figure 6). The highest number of infested areas occurred in East Java in 2011, with more than 140.000 ha affected. Similarly, the number of infested areas in Central Java reached its peak in the same year. In West Java, the highest point occurred in 2010. Although the number of BPH-infested areas fluctuated, following the implementation of recommendations (after 2013), the infested areas decreased to less than 50.000 ha in all three provinces. This provides strong evidence that IPM can effectively reduce BPH-infestation. However, in 2020, the number of BPH infested areas in these provinces to be on the rise, signaling the potential for larger BPH outbreaks in Java. This is a cause for concern and should be addressed.

Analysis of pesticide use patterns in Java

From 2017 until 2018 in Indramayu (Table 5), it was observed that pesticide use patterns in Java remained improper. Most farmers used insecticides containing active ingredients such as abamectin from the avermectin group and dimehypo. Other frequently used active ingredients included pymetrozine, fipronil, imidacloprid, and chlorpyrifos. Interestingly, in both Semarang in 2013 and Indramayu in 2017, neonicotinoid (i.e. dimehypo) and neristoxin (i.e. imidacloprid) were among the most commonly used active ingredients. This indicates that the pesticide use patterns in both years in Java show no significant difference. A study conducted in Padang City, Indonesia, by Syahrawati et al. (2019) also found that farmers used synthetic insecticides with active ingredients pimetrozin, imidacloprid, bpmc, fipronil, and carbofuran, which aligns with our findings Similarly a study by Matsukawa-Nakata et al. (2019) in Vietnam reported the frequent use of active ingredients like imidacloprid, fipronil, emamectin-benzoate, pymetrozine, and thiamethoxam. Resistance to imidacloprid was reported in China and other Asian countries (Wang et al. 2008; Catindig et al. 2009). Another study in China reported extremely high resistance to imidacloprid and a reduction in BPH susceptibility to pymetrozine (Zhang et al. 2014). According to Khoa et al. (2018), there may be a buildup of general metabolic resistance, either alone or in combination with the emergence of target-site resistance mutations.

In Figure 4, 16% of respondents in the Banyubiru Sub-district in 2013 applied pesticides in a mixture of more than two pesticides. Similar results were found by Syahrawati et al. (2019) in Padang City, where farmers mixed two to three types of insecticides, and by Prihandiani et al. (2021) in Indramayu, which showed that 38 percent of farmers mixed three pesticides, while 21 percent of farmers mixed four to five pesticides for application. Prihandiani et al. (2021) also reported that the most common mixture was abamectin + dimehypo + pymetrozin. Our study found that the use of more than two pesticides was not based on awareness but rather resulted from the inability to purchase more pesticides. These results are supported by findings in Indramayu in 2017 (Figure 5). This suggests that over the years, the KAP of farmers in Java still remained relatively low. Low quality KAP among farmers can lead to environmental problems, such as pest resistance and resurgence, water, and soil pollution, as well as the contamination of harmful compounds affecting humans and animals due to unsafe practices.

The results in Indramayu in 2017 align with our previous findings in Banyubiru in 2013, indicating that farmers tend to lack proper information about pesticides. The tendency for low KAP among farmers was also described by Uddin et al. (2019), where 64.94% of pesticide selections were influenced by insecticide dealers, 28.89% were guided by agricultural officers, 4% received advice from neighbouring farmers, and only 2% independently chose pesticides. Most farmers selected pesticides with the help of kiosk salespersons, often leading to improper pesticide use as dealers prioritize their most profitable over the best recommendation. A study by Matsukawa et al. (2015) demonstrated that farmers severely affected by BPH followed the advice of sellers in pesticide selection. According to Matsukawa-Nakata et al. (2019), the application of selective insecticides did not contribute to reducing the planthoppers densities; instead it indicated that improper insecticide application could potentially lead to the development of insecticide resistance. All these studies underscore the link between farmers' KAP and BPH infestation.

From 2002 to 2014, the registration of pesticides for BPH increased by 225 percent, from 48 to 156 products. Furthermore, the registration of pesticides in general also increased (Trisyono 2016). A study conducted by Prihandiani et al. (2021) in Indramayu reported high pesticide usage in 2013–2014, followed by severe planthopper outbreaks in 2016. The excessive use of pesticides has continued until 2021. Stocks of rice insecticides, especially those for brown planthopper (BPH), rice stem borer (RSB), and BPH & RSB in the three largest provinces of Java, were quite high, with more than 20.000 kg in each province in June 2021. This indicates that massive pesticide use is ongoing in Java, which may lead to BPH outbreaks in the future due to resistance and resurgence, stemming from unhealthy agroecosystem. The resurgence occurs both ecologically by erasing natural enemies, and physiologically by increasing fecundity, extending the life of imagoes, and improving the survival chances of nymphs.

The detrimental effects of improper pesticide use still need to be emphasized to Indonesian farmers, as they tend to rely on conventional methods to manage pests and diseases. They may struggle to apply techniques or technologies provided in coaching programs. Yuantari et al. (2015) stated that improved knowledge and attitudes are insufficient to change farmers' behavior, and more interactive and participatory training models are needed. This implies that the current government-led IPM-based programs should be enhanced and developed. Thus, the KAP of farmers can be improved and the IPM concept can be applied more comprehensively applied.

As a result, Plant Clinic IPB University recommends suspending the insecticide mass spraying program to prevent further plant damage. In the next rice crop season, BPH outbreak threats can be mitigated if farmers adopt ecologically sound pest and soil management practices. Intensive extension programs on IPM and soil management are urgently needed.

CONCLUSION

The rapid assessment strongly suggests that the BPH outbreak is a result of insecticide-induced resurgence. It is suspected that the local BPH population has developed resistance to deltamethrin, imidacloprid, and dimehypo. The analysis of farmers' KAP indicated inadequate knowledge about judicious pesticide use, resulting in prophylactic insecticide sprays. The application of banned and improper insecticides and the repeated use of the same insecticide active ingredients for an extended period are suspected causes of BPH resistance and resurgence.

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