IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Efficacy of insecticides mixture to brown planthoppers (*Nilaparvata lugens*) and its effect on natural enemies

To cite this article: Rahmini *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1160** 012052

Efficacy of insecticides mixture to brown planthoppers (*Nilaparvata lugens*) and its effect on natural enemies

Rahmini[1*], E H Iswanto[2], H Suparno[3] and B Nuryanto[1]

[1] National Agency for Research and Innovation of Republic of Indonesia, Cibinong Science Center Jl. Raya Bogor Km 46 Cibinong, West Java, Indonesia
[2] Indonesian Center for Rice Research, Jl. Raya 9 Sukamandi, Subang 41256, West Java, Indonesia
[3] PT. Royal Agro Indonesia, Menara 165, 12A Floor, Unit B, Jl. TB Simatupang, South Jakarta 12560, Indonesia

[*] Email: a.rahmini@gmail.com

Abstract. Insecticides applications are one of the components to control brown planthoppers pest that are applied in large scale by farmers. In the field, some farmers mix different active ingredients of insecticides to control brown planthoppers. This study was aimed to find out the efficacy of mixed insecticides to brown plant hoppers and the effect on natural enemies in the field. The research was carried out in Pemalang Regency, Central Java, in 2016/2017 rice planting season. There were eleven treatments with three replications in 5x8 m2 plots using randomized completed block design. Two successive sprays of selected insecticides were applied with sprayer at 14 days interval. Insecticides Pymetrozine 480 + Imidacloprid 160 (150+50), Pymetrozine 480 + Imidacloprid 160 (75+25), Pymetrozine 185 + Buprofezin 240 (150+194,59), Pymetrozine 185 + Buprofezin 240 (75+97,3), and Buprofezin 240 + Fipronil 40 (100+16,67) effectively controlled the population of brown planthopper with the efficacy as follows 96.78%; 94.27%; 96.45%; 96.71%; and 94.01%. Insecticides mixtures tested did not affect the population of natural enemies such as spiders, *Paederus*, and *C. lividipennis*.

Keywords: agriculture, pest management, rice

1. Introduction

Brown planthopper, *Nilaparvata lugens* Stål (Hemiptera: Delphacidae), is one of the important insect pests and has economic value in most rice-producing Asian countries. In 2019, Directorate of Plant Protection reported 30846 ha of rice were damaged by brown planthoppers. Nymphs and imago from brown planthoppers cause direct damage by sucking nutrients from rice photosynthesis process and indirectly by spreading viruses such as rice grassy stunt virus (RGSV) and rice ragged stunt virus (RRSV). Brown planthoppers are monophagous herbivores in rice that have the ability to migrate. Adult brown planthoppers have a variety of wings, which are, long and short winged. Short wings cannot migrate, but produce a greater number of eggs; brown planthoppers with long wings can fly between regions to infest rice plantings to survive the next growing season. It was this combination of functions of the two wing types that led to explosion of the population of brown planthopper [1].

Insecticides are only used when brown planthopper population has reached the threshold of control. Control with insecticides is often ineffective due to the type of insecticide, the timing of application and improper dosage. This causes natural enemies killed and brown planthoppers triggered. Insecticides can also affect plant physiology so that rice resistance to brown planthoppers would change [2]. The continued use of these types of insecticides without following the rules has resulted in rapid development of insecticide resistance. Brown planthopper population had moderate resistance to imidacloprid and cypermethrin in Subang District, West Java Province [3]. In addition, the ability of insecticides to control brown planthoppers can cause resurgence. Resurgence is the process of increasing the population of brown planthoppers after insecticide application with a higher growth rate than those in no insecticide applications. The resurgence of brown planthoppers is caused by several factors, such as poor spraying methods, natural enemies killed, changes in plant physiology so that planthoppers prefer it, or changes in planthoppers physiology due to insecticides [4]. Some parasitoids such as *Telenomus rowani, Oligosita sp.* species are sensitive to chemical insecticid *Rynaxypyr Fipronil, Dinotefuran, Pymetrozine, Imidacloprid*, and BPMC [5]. Inpres (Presidential Instruction) No. 3 of 1986 prohibited the use of 57 insecticides of the organophosphate group (*Chlorpyrifos* and *Diazinon*) and only allows 10 insecticides from the carbamate group (BPMC, MICP, and carbofuran) and growth regulator (*Buprofezin*) to control rice pests. Currently various active ingredients of insecticides are widely circulated and are used to control brown planthoppers such as *Fipronil, Buprofezin, Imidacloprid, Pymetrozine* and *Dinotefuran*. Each of these active ingredients is classified according to how it works in killing insects (brown planthoppers), for example group 16 (*Buprofezin*) inhibits molting process in brown planthoppers nymphs, and group 9B (*Pymetrozine*) inhibits feeding activities [6].

The use of pesticides by farmers is very highly intensive, even exceeding safe limits. The farmers are common to use two or more types of pesticides which the compatibility is unknown. Some farmers mix insecticides, even without realizing the impact on environment. However, many also use insecticide mixture that has the opposite effect (antagonist). This practice is very dangerous because the number of insecticides used has multiplied. Moreover, if in addition to excessive doses, the targeted pests remain uncontrollable, causing damage on environment, and causing pest resistance. On the other side, synergistic mixed pesticides have greater efficacy than single pesticides because they can control insects at a time, reduce the concentration of chemicals needed, and have synergistic work in pest control [7]. Such a strategy has been recognized as an effective method of extending the service life of insecticides, and is also a recognized strategy for controlling brown planthopper populations that are already resistant to insecticide by having double work [8-10]. This study was aimed to determine the effectiveness of insecticides mixed with active ingredients against brown planthoppers and its natural enemies in the field. The result of the study was expected to be able to provide the information on which insecticides mixture that would be effective and less affected the natural enemies.

2. Material and Methods

The test was carried out in Tambakring Village, Pemalang Sub-district, Central Java in 2016 Planting Season. The ingredients used in this test were various dose compositions of insecticides made from active ingredients *Pymetrozine + Imidacloprid*, *Pymetrozine + Buprofezin*, *Buprofezin + Fipronil*, *Buprofezin + Imidacloprid*, as a comparison were *Dinotefuran*, and *Pymetrozine*. We used different concentrations of marketed insecticides, such as Pymetrozine 480 WG, Imidacloprid 160 WG, *Pymetrozine* 185 WG, *Buprofezin* 240, *Fipronil* 40, and I*midacloprid* 120. The mixture of the insecticide's concentrations used in the treatments was lower than the initial dose (± 15 – 80%), except the single insecticides as comparison, *Dinotefuran* and *Pymetrozine* used full dosages. Both of single insecticides are commonly used by farmers to control brown planthoppers. *Dinotefuran*, *Buprofezin*, *Fipronil* are contact insecticides, whereas *Pymetrozine, Imidacloprid* are systemic insecticides. The test used a randomized group design with 11 treatments and 3 tests with a plot size of 5 x 8 m2. The treatments were as follows :

Table 1. Treatments for the Experiment.

No	Insecticides	Active ingredients /ha (treatments)	
1	*Pymetrozine* 480 + *Imidacloprid* 160 WG or SC	150 + 50	
2	*Pymetrozine* 480 + *Imidacloprid* 160 WG or SC	75 + 25	
3	*Pymetrozine* 185 + *Buprofezin* 240 WG or SC	150 + 194.59	
4	*Pymetrozine* 185 + *Buprofezin* 240 WG or SC	75 + 97.3	
5	*Buprofezin* 240 + *Fipronil* 40 SC	100 + 16.67	
6	*Buprofezin* 240 + *Fipronil* 40 SC	50 + 8.33	
7	*Buprofezin* 240 + *Imidacloprid* 120 SC or SL	100 + 50	
8	*Buprofezin* 240 + *Imidacloprid* 120 SC or SL	50 + 25	
9	*Dinotefuran* 20 SG	400	Full dose
10	*Pymetrozine* 50 WG	250	Full dose
11	Untreated/control		

The rice variety used was Ciherang variety. Rice seedlings aged 21 days were planted in each plot with a planting distance of 25 x 25 cm. The insecticides application was carried out after initial observations found that brown planthopper populations in the rice field reached the economic threshold, namely 9 planthoppers/hills at the age of <40 days after planting or 18 planthoppers / hills at the age of >40 days after planting. The treatments were applied with an interval of once in every 2 weeks, the volume of water as an insecticide solvent used was 300 l / ha.
Direct observations on 30 rice hills of samples on each plot were taken diagonally to cover brown planthopper populations, also to observe the natural enemies found on the rice plants. Observations were carried out at 7 and 14 days after application. The percentage of efficacy of the insecticide (EI) to brown planthoppers tested at 1 or 2 weeks after the first application used Abbot's Formula, as follows:

$$EI = \left(\frac{Ca - Ta}{Ca}\right) \times 100\% \tag{1}$$

No : Efficacy of insecticides tested (%)
Ta : Brown planthoppers populations on insecticide treatment pots were tested after insecticide spraying.
Ca : Populations of brown planthoppers on control pots after insecticide spraying

After the data was processed with Abbot Formula, then continued with Duncan's Multiple Range Test (DMRT) at a level of 5%, using the SAS program.

3. Results and Discussion

The results of preliminary population observations showed that the population density of brown planthoppers was evenly distributed to all experimental plots. The brown planthoppers population in the rice field was high with a range of 1251 – 1481 planthoppers / 30 hills or about 41-52 planthoppers / hills. The first application was carried out 1 day after the initial population observation or at 6 weeks after planting (MST). Seven days after insecticide application, the brown planthopper population was suppressed to about 6-12 planthoppers/hills. In control plots or without treatment, the population remained high at around 33 planthoppers/hills and was noticeably higher than all treatments. In general, the entire insecticide treatment could suppress the population of brown planthoppers. Insecticide treatment mixture *Pymetrozine* 185 + *Buprofezin* 240 (150+194.59) suppressed planthopper population up to 191.3 planthoppers/30 hills or with an efficacy of up to 80.42%. Other treatments, namely *Pymetrozine* 480 + *Imidacloprid* 160 (150+50), *Pymetrozine* 480 + *Imidacloprid* 160 (75+25), *Pymetrozine* 185 + *Buprofezin* 240 (75+97.3), *Buprofezin* 240 + *Fipronil* 40 (100+16.67) had the same effect as *Pymetrozine* 185 + *Buprofezin* 240 (150+194.59) in suppressing planthopper population. The active insecticide *Pymetrozine* had the same ability to suppress brown planthopper populations as the aforementioned mixed insecticides, with an efficacy of 75.07% (Table 2). Meanwhile, *Dinotefuran*, as the sole active ingredient in this experiment, had an efficacy of 60.47% and had a different influence on the brown planthopper populations with all mixed insecticides tested.

In the second observation, which was two weeks after the first application (T1+14), the population of brown planthopper in general had increased again and had also been evenly distributed to all treatment plots, except to control plots. Brown planthopper populations on all real insecticide treatments were lower than the controls. The increase in brown planthoppers in 2nd application was due to the population in the field having entered 2nd generation, from the rest of the population that escaped or did not die during the first spraying.

Table 2. Efficacy of insecticide active ingredients against brown planthopper populations.

No	Treatment	Initial population *	T1+7		T1+14		T2+7	
			No. of bph*	Efficacy (%)	No. of bph*	Efficacy (%)	No. of bph*	Efficacy (%)
1	*Pymetrozine* 480 + *Imidacloprid* 160 (150+50)	1377.7 a	193.7 e	80.18	593.0 b	50.62	33.0 c	96.78
2	*Pymetrozine* 480 + *Imidacloprid* 160 (75+25)	1428.3 a	202.3 de	79.30	673.0 b	43.96	58.7 c	94.27
3	*Pymetrozine* 185 + *Buprofezin* 240 (150+194,59)	1417.3 a	191.3 e	80.42	617.0 b	48.63	36.3 c	96.45
4	*Pymetrozine* 185 + *Buprofezin* 240 (75+97,3)	1439.7 a	210.3 de	78.48	576.7 b	51.98	33.7 c	96.71
5	*Buprofezin* 240 + *Fipronil* 40 (100+16,67)	1427.7 a	205.3 de	78.99	602.7 b	49.82	61.3 c	94.01
6	*Buprofezin* 240 + *Fipronil* 40 (50+8.33)	1480.7 a	272.3 c	72.13	616.3 b	48.68	229.7 b	77.56
7	*Buprofezin* 240 + *Imidacloprid* 120 (100+50)	1491.0 a	251.7 cd	74.25	630.3 b	47.52	549.3 a	46.32
8	*Buprofezin* 240 + *Imidacloprid* 120 (50+25)	1460.0 a	274.0 c	71.96	675.0 b	43.80	415.0 a	59.44
9	*Dinotefuran*	1452.0 a	386.3 b	60.47	675.7 b	43.74	59.3 c	94.20
10	*Pymetrozine*	1482.3 a	243.7 cd	75.07	576.0 b	52.04	105.0 bc	89.74
11	Control	1448.3 a	977.3 a		1201.0 a		1023.3 a	

Notes: T1 first application
T2 second application
T+7 7 days after application
T+14 14 days after application
*The number followed by the same letter in the same column in each treatment did not differ significantly in the DMRT test with a significance level of 5%
bph = brown planthoppers

At one week after 2nd application, the population of brown planthoppers on some treatments decreased drastically. The population range on the treatment plot was 33 – 549 planthoppers/30 hills compared to the control of 1023 brown planthoppers/30 hills. All combinations of *Pymetrozine* with *Imidacloprid*, *Buprofezin* could reduce population significantly, also combination *Buprofezin* 240 with

Fipronil 40 (100+16,67). In addition, the five applications of mixed insecticides had the same effect as the single comparator insecticides, *Dinotefuran* and *Pymetrozine*, on brown planthopper population. The second application of *Buprofezin* 240 + *Fipronil* 40 (50+8.33) had a different effect on brown planthopper population with both doses of mixed insecticide application *Buprofezin* and *Imidacloprid*. The application of insecticide mixture *Pymetrozine* 480 + *Imidacloprid* 160 (150 + 50) could suppress planthopper populations up to 96.78%. Also, on the insecticide treatment *Pymetrozine* 480 + *Imidacloprid* 160 (75+25) could suppress 94.27%, *Pymetrozine*185 + *Buprofezin* 240 (150+194.59) could suppress 96.45%, *Pymetrozine* 185 + *Buprofezin* 240 (75+97.3) 96.71%. The combination of *Buprofezin* 240 + *Fipronil* 40 (100+16,67) could suppress 94.01% of brown planthopper population.

Table 3. Spider population at various doses of insecticides mixture.

No	Treatment	initial population	Spider population (/30 hills)		
			T1+7	T1+14	T2+7
1	*Pymetrozine* 480 + *Imidacloprid* 160 (150+50)	31.7 a	28.7 a	26.7 a	21.3 a
2	*Pymetrozine* 480 + *Imidacloprid* 160 (75+25)	30.0 a	32.3 a	25.7 a	25.0 a
3	*Pymetrozine* 185 + *Buprofezin* 240 (150+194,59)	29.3 a	29.7 a	28.7 a	23.0 a
4	*Pymetrozine* 185 + *Buprofezin* 240 (75+97,3)	23.7 a	26.7 a	28.0 a	22.7 a
5	*Buprofezin* 240 + *Fipronil* 40 (100+16,67)	31.3 a	29.0 a	28.3 a	22.7 a
6	*Buprofezin* 240 + *Fipronil* 40 (50+8.33)	29.0 a	30.3 a	25.0 a	23.3 a
7	*Buprofezin* 240 + *Imidacloprid* 120 (100+50)	26.0 a	28.7 a	27.0 a	26.3 a
8	*Buprofezin* 240 + *Imidacloprid* 120 (50+25)	29.7 a	31.3 a	28.3 a	28.3 a
9	*Dinotefuran*	32.0 a	29.3 a	23.7 a	21.7 a
10	*Pymetrozine*	25.7 a	29.7 a	24.7 a	23.0 a
11	Control	25.3 a	27.0 a	28.7 a	22.0 a

Note: T1 first application
T2 second application
T+7 7 days after application
T+14 14 days after application
*The number followed by the same letter in the same column in each treatment did not differ significantly in the DMRT test at level of 5%.

Based on these results, two applications were required to reduce the population, because from the first application there were still planthoppers that passed and restored the population level, so a second application was needed to reduce the planthopper population level to below the economic threshold. *Pymetrozine* mainly serves as an anti-feeding that causes starvation and death in brown planthoppers and is not neurotoxin in nature. Electrical Penetration graph (EPG) data showed that *Pymetrozine* delayed the time of pinching by brown planthoppers on the phloem tissues of rice plants [11]. During the study, *Pymetrozine* was the best treatment to reduce brown planthopper population. This finding was similar with the study reported from India, not only brown planthoppers, it also affected white back planthoppers [12]. The third-generation neonicotinoid, *Dinotefuran*, is a new furanicotinyl insecticide that is not a mutagen, neurotoxin or reproductive poison. This insecticide works through contact and feeding tract causing a halt in eating behavior and resulting in death [13]. Imidacloprid is a systemic insecticide that translocate rapidly through plant tissues following application [14]. This active ingredient is used by rice farmers widely, reported resistance of brown planthoppers to *Imidacloprid.* It took ten generations to reduce the resistance ratio of brown planthoppers in Banyumas, Central Java, from 150.39 to 38.14-times after the selection pressure was removed [15]. Mixing pesticides with different mode due to the mechanism needed to resist each pesticide in the mixture may not be widely distributed or exist in arthropod pest populations, the action may postpone the development of resistance within arthropod pest populations [16].

Dominant natural enemies of brown planthoppers include spiders, Paederus and Cyrtorhinus lividipennis. Spiders are one of the natural enemies or predators for brown planthoppers. Spiders are generalist predators. Based on observations, the population of these natural enemies on all experimental plots did not differ significantly from control. In other words, the application of mixed insecticides *Pymetrozine* + *Imidacloprid*, *Pymetrozine* + *Buprofezin*, and *Buprofezin* + *Fipronil*, as well as insecticides with active ingredients *Dinotefuran* and *Pymetrozine* did not affect spider population (Table 3).

Table 4. *Paederus* population on various doses of insecticides mixture.

No	Treatment	initial population		Population of *Paederus* (/30 hills)					
				T1+7		T1+14		T2+7	
1	*Pymetrozine* 480 + *Imidacloprid* 160 (150+50)	22.7	a	21.7	ab	10.0	a	7.0	ab
2	*Pymetrozine* 480 + *Imidacloprid* 160 (75+25)	23.3	a	21.7	ab	10.0	a	7.7	ab
3	*Pymetrozine* 185 + *Buprofezin* 240 (150+194,59)	24.7	a	19.0	ab	11.7	a	6.7	ab
4	*Pymetrozine* 185 + *Buprofezin* 240 (75+97,3)	23.7	a	17.0	ab	11.7	a	6.0	ab
5	*Buprofezin* 240 + *Fipronil* 40 (100+16,67)	22.0	a	25.7	a	13.3	a	5.0	b
6	*Buprofezin* 240 + *Fipronil* 40 (50+8.33)	23.0	a	21.7	ab	14.0	a	6.7	ab
7	*Buprofezin* 240 + *Imidacloprid* 120 (100+50)	23.3	a	22.7	ab	12.3	a	10.0	ab
8	*Buprofezin* 240 + *Imidacloprid* 120 (50+25)	27.0	a	25.7	a	9.7	a	10.0	ab
9	*Dinotefuran*	27.7	a	15.7	b	8.3	a	9.7	ab
10	*Pymetrozine*	25.7	a	25.3	a	13.0	a	5.7	ab
11	Control	28.3	a	21.0	ab	11.3	a	11.0	a

Notes: T1 first application
T2 second application
T+7 7 days after application
T+14 14 days after application
*The number followed by the same letter in the same column in each treatment did not differ significantly in the DMRT test with level of 5%.

Paederus fuscipes, otherwise known as tomcats, is an insect that is common in rice field agroecosystems, and is a common predator. This insect belongs to beetles from the Ordo Coleoptera, Family Staphylinidae. *P. fuscipes* an active predator of brown planthoppers and plays an important role in preventing the explosion of brown planthopper population by preying on macropterous brown planthoppers [17]. These natural enemies population before insecticide application ranged from 22.0 – 28.3 individu/30 hills. In observation one week after the first application (T1+7) of spraying mixed insecticides near the entire treatment had no effect on *Paederus* populations except *Dinotefuran*. *Paederus* populations were highest at *Buprofezin* 240 + *Fipronil* 40 (100+16.67) and *Buprofezin* 240 + *Imidacloprid* 120 (50+25) treatment which was about 25.5 planthoppers/30 hills. In subsequent observations (T1+14) the *Paederus* population did not differ significantly between the entire treatment and the control plot (Table 4). At one week after the second insecticide application (T2+7), almost the entire *Paederus* population declined, but this decrease was likely not due to insecticide application, since the control plots experienced the same thing and did not differ significantly from other treatment plots, except for the *Buprofezin* 240 + *Fipronil* 40 treatment plots (100+16.67).

Table 5. Population of *Cyrtorhinus lividipennis* at various doses of insecticides mixture.

No	Treatment	initial population		Population of *Cyrtorhinus* (/30 hills)					
				T1+7		T1+14		T2+7	
1	*Pymetrozine* 480 + *Imidacloprid* 160 (150+50)	52.3	a	21.0	c	14.7	ab	3.0	a
2	*Pymetrozine* 480 + *Imidacloprid* 160 (75+25)	44.7	a	29.0	abc	13.7	b	2.3	a
3	*Pymetrozine* 185 + *Buprofezin* 240 (150+194,59)	44.7	a	29.7	abc	12.0	b	1.7	a
4	*Pymetrozine* 185 + *Buprofezin* 240 (75+97,3)	52.0	a	41.0	ab	16.0	ab	1.7	a
5	*Buprofezin* 240 + *Fipronil* 40 (100+16,67)	44.3	a	35.0	abc	15.3	ab	3.3	a
6	*Buprofezin* 240 + *Fipronil* 40 (50+8.33)	48.3	a	31.0	abc	14.0	ab	6.3	a
7	*Buprofezin* 240 + *Imidacloprid* 120 (100+50)	47.7	a	27.3	abc	13.7	ab	6.3	a
8	*Buprofezin* 240 + *Imidacloprid* 120 (50+25)	49.0	a	25.0	abc	18.3	ab	5.7	a
9	*Dinotefuran*	51.0	a	35.7	abc	12.0	b	3.0	a
10	*Pymetrozine*	56.3	a	24.7	bc	13.7	ab	3.0	a
11	Control	52.7	a	39.3	a	22.3	a	13.0	a

Notes: T1 first application
T2 second application
T+7 7 days after application
T+14 14 days after application
*The number followed by the same letter in the same column in each treatment did not differ significantly in the DMRT test with level of 5%

The population of brown planthoppers, *C. lividipennis*, before insecticide application its population ranged from 44.7 – 56.7 planthoppers/30 hills and did not differ significantly between treatments and controls. In observation after application (T1+7) it was seen that in the insecticide plots *Pymetrozine* 480 + *Imidacloprid* 160 (150 + 50) and *Pymetrozine* had a tendency to decrease the population of *C. lividipennis* compared to controls (Table 5). In subsequent observations (T1+14), it was seen that the population density of *C. lividipennis* on the plots treated with insecticides *Pymetrozine* 480 + *Imidacloprid* 160 (75 +25), *Pymetrozine* 185 + *Buprofezin* 240 (150 + 194.59) and *Dinotefuran* its effect was noticeable two weeks after application. After the second insecticide application (T2+7) all comparators did not differ significantly from the population density on the control plot. Based on these data, it could be concluded that the use of insecticides did not affect the population of natural enemies of *C. lividipennis*. Compared with other insecticides, *Pymetrozine* was considered as far less toxic than insecticides such as synthetic pyrethroids, organophosphate, and neonicotinoids tested [18].

4. Conclusion

The mixed insecticides application, insecticide *Pymetrozine* 480 + *Imidacloprid* 160 (150+50), *Pymetrozine* 480 + *Imidacloprid* 160 (75+25), *Pymetrozine* 185 + *Buprofezin* 240 (150+194.59), *Pymetrozine* 185 + *Buprofezin* 240 (75+97.3), and *Buprofezin* 240 + *Fipronil* 40 (100+16.67) effectively controlled the population of brown planthoppers in rice plants. The highest efficacy was *Pymetrozine* 480 + *Imidacloprid* 160 (150+50) or could suppress 96.78% of brown planthopper population and not significantly different from single active ingredients *Pymetrozine* and *Dinotefuran*. The use of mixed insecticides did not affect the population of natural enemies of brown planthoppers including spiders, *P. fuscipes*, and *C. lividipennis*.

Acknowledgments
We thank Nono Sumaryono and Endang Data for their assistance in the field during the study.

Reference
[1] Hu J, Xiao C and Yuqing H E 2016 *Rice* **9** 1-12
[2] Nanthakumar M, Lakshmi V J, Bhushan V S, Balachandran S M and Mohan M 2012 *Pesticide Biochemistry and Physiology* **102** 146–152
[3] Effendi B S, Iswanto E H and Munawar D 2016 *J. Penelitian Pertanian Tanaman Pangan* **35** 99-107
[4] Uddin A B M A, Islam K S, Jahan M, Ara A and Khan M A I 2020 *J. Agric*. **18** 117-128
[5] Effendi B S, Iswanto E H, Munawar D and Sumaryono N 2016 *J. Agrikultura* **27** 49-58
[6] Irac, 2012 IRAC MoA classification scheme [online] available: http://www.irac-online.org/documents/moa-classification/?ext=pdf
[7] Corbel V, Chandre F, Darriet F, Lardeux F and Hougard J M 2003 *Medical and Veterinary Entomology* **17** 158–164
[8] McKenzie J A 1996 *Applying the theory, the better management of resistance and pests: Ecological and Evolutionary Aspects of Insecticide Resistance* (San Diego: Academic Press) pp 149-173
[9] Tao L M, Yang J Z, Zhuang P J and Tang Z H 2006 *Pest Management Sci.***62** 86-90
[10] Ghafoor A, Khan M S, Mahmood A, Ahmad F, Hasan M and Anees A R 2011 *J. World Applied Sci.* **13** 90-94
[11] He Y, Chen L, Che J, Zhang J, Chen L, Shenc J and Zhud Y H 2011 *Pest Manag Sci* **67** 483–491
[12] Adhikari B, Padhi J and Dohling P N K 2019 *J. Entomology and Zoology Studies* **7** 528-531
[13] Ghosh A, Samanta A and Chatterjee M L 2014 *African J. Agric. Research* **9** 750-754.
[14] Gervais J A, Luukinen B, Buhl K and Stone D 2019 Imidacloprid Technical Fact Sheet [online] available: http://npic.orst.edu/factsheets/archive/imidaclop rid.html
[15] Diptaningsari D, Trisyono Y A, Purwantoro A and Arman W A 2020 *J. Perlindungan Tanaman Indonesia* **24** 61–67
[16] Cloyd R A 2010 *Pesticides-Formulations, Effects, Fate* ed M Stoytcheva (Croatia: InTech) pp 69-80
[17] Wagiman F X, Tamba B and Rinarti I 2014 *ARPN Journal of Agricultural and Biological Sci.* **9** 117-121
[18] Jansen J P, Defrance T and Warnier A M 2011 *BioControl* **56** 759–770