IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Population Dynamic of Brown Plant Hopper, Predators and Neutral Insects in Irrigated Rice of Yogyakarta after Insecticides Application

To cite this article: Arlyna B. Pustika *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1177** 012020

Population Dynamic of Brown Plant Hopper, Predators and Neutral Insects in Irrigated Rice of Yogyakarta after Insecticides Application

Arlyna B. Pustika[1*], Sudarmaji[13], Mahargono Kobarsih[2], Siti Dewi Indrasari[23], Kristamtini[1], Setyorini Widyayanti[1], Arif Anshori[1], Heni Purwaningsih[2] and Kiki Yolanda[3]

[1]Research Centre for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation (BRIN), Cibinong Science Center, Jl. Raya Jakarta – Bogor, KM. 46, Cibinong, Bogor, West java 16911 Indonesia.
[2]Research Centre for Food Technology and Processing, Research Organization for Agriculture and Food, National Research and Innovation (BRIN), Jl. Jogja – Wonosari KM. 31.5, Playen, Gunungkidul, DI Yogyakarta 55861 Indonesia.
[3]Assessment Institute of Agricultural Technology of Yogyakarta, Jl. Stadion Maguwoharjo No. 22 Ngemplak, Sleman, DI Yogyakarta, Indonesia.
*Email: arlynapustika@gmail.com; arlyna.budi.pustika@brin.go.id

Abstract. Brown Plant Hopper (BPH) infestation in irrigated rice agroecosystem resulted yield loss. The application of insecticides by farmers are usually excessive, reducing pest population and negatively affecting the predators. This research aimed to define the impact of insecticides on the population dynamic of BPH, predator and neutral insects which influenced rice yield. Research was conducted at Yogyakarta, Indonesia, during May to September 2021. Randomized Block using four replications was applied. Rice varieties Inpari 32 HDB and Inpari 42 GSR were planted. Insecticide with active ingredient spinetoram 120 g/l and triflumezopyrim 106 g/l were applied to the rice plant on day 40th then pimetrozin 50% was applied at day 50th. Results showed that BPH population was reduced from 30 -50 nymph per 30 plants to 10 nymph at day 12th after pimetrozin 50% application or at the day 2nd after spinetoram and triflumezopyrim insecticides application until day 50th. In contrast, BPH population in all insecticide plants was significantly lower than in all control and did not increase until harvest. On the other side, predators such as *Paederus* sp and Coccinelids were not affected by all insecticides, except *Ophionea* sp, Spiders and *Cythorinus* sp. However, their population recovered at day 30th after first insecticides application. Within the fluctuated population of BPH, rice productivity of Inpari 32 HDB and Inpari 42 GSR applied with insecticides were 9.52 ton ha^{-1} and 10.60 ton ha^{-1}, while Inpari 32 HDB control and Inpari 42 GSR control 9.44 ton ha^{-1} and 10.72 ton ha^{-1}

1. Introduction

Brown Plant Hopper (BPH) *Nilaparvata lugens* Stal. is one of the foremost rice pest, resulting significant yield loss, both in irrigated rice agroecosystems and rainfed in Indonesia, including the Yogyakarta Special Region. In Indonesia, peak attacks of BPH occurred in 2010 and 2011, reaching 137,768 ha and 218,060 ha. Particularly in West Java in early 2010, BPH from 127 ha of “puso” rice spread up and caused an outbreak at 60,488 ha. With an average yield loss of 1-2 tons/ha, the economic value of the grain lost reaches IDR 1,102 T and IDR 1,74 T, respectively, in 2010 and 2011 [1].

BPH damages rice by sucking phloem sap resulting in chlorophyll reduction, decreasing either the content of protein in leaf and photosynthesis rate [2]. Infested plants showed deterioration, small growth, and leaves turn to yellow, then severe damage resulting hopper burn or dry die. BPH has exponential growth which potentially damage rice crops after reach generation 2-3, because there will be abundant nymphs which live in high density at the base stem of rice tillers. The infestation can reach BPH as 400-1000 at each plant, even more than 1000 BPH at every plant when their population is very high.

Regarding its potential to migrate up to 200 km [3], BPH has turned out to be a worldwide pest and broadly dispersed in South East Asia (Indonesia, Malaysia, Sarawak, Bangladesh, Cambodia, Thailand, Vietnam, India, Taiwan and the Philippines), East Asia (Korea, Japan, and China) and the Australian (Solomon, Caledonia, Fiji, New Gunea and Australia) [4]. Rice cropping pattern influenced by climate change affects this insect's behavior. La Nina with heavy rainfall cause high humidity in the dry season, which might activate the development of BPH and thrive population outbreak. In some areas, asynchronous planting also triggered the second explosion of the BPH population. Farmers planting rice forward each other caused the availability of water anytime. The population blast of BPH is also triggered by farmers' inaccurate application of insecticides and a high usage of unrecommended insecticides. Weak monitoring of the BPH population severelydamages rice crops [1]. Concerning this situation, there was presidential regulation (Inpres No.3, the year 1986) about 57 insecticides prohibited from controlling BPH due to resurgence impact.

High-level attack of BPH causes increasing of farmers' dependency on synthetic pesticides. Concerning the rice plants damage and the high BPH inhabitants, farmers were forced to seek the procurement of synthetic pesticides. However, due to farmers' limitations in capital, knowledge, and skills regarding synthetic pesticides, the practice of pesticide application by farmers is inappropriate, including the right active ingredient, concentration, and dose. These limitations forced farmers to spray pesticides with doses less than recommended. Scientifically, it can be proven that spraying pesticides that are not in the right dose and concentration can encourage BPH resistance and resurgence, increasing BPH population faster than before spraying. Many types of insecticide formulations currently permitted by the government to be marketed and used on rice plants have been proven to encourage BPH resurgence [5]. Excessive use of pesticides distresses the BPH and natural enemies equilibrium, triggering the loss of natural enemies and pest resurgence.

Regarding other predators, spiders play a substantial role to control BPH. Spiders prey 15-20 of BPH imago per day [6, 7, 8]. Natural enemies, particularly predators of BPH, are *Cyrtorhinus lividipennis* (egg predator), spiders as nymph predators such as *Paederus fuscifes*, *Ophionea nigrofasciata*, *Argiope catenulate*, *Araneus inustus*, *Pardosa* (Lycosa) *pseudoannulata*, *Oxyopes javanus*, *Clubiona javanicola*, *Calitrichia formosana*, and *Tetragnatha maxillosa* [9]. Other predators which can be found are coccinellids and libellulids [10].

The application of synthetic insecticides to control BPH commonly still occurs in Indonesia, including Yogyakarta. This experiment aimed to define the dynamic of BPH population and the natural enemies in irrigated rice of Yogyakarta after insecticide application.

2. Materials and Methods

2.1. Sub-Materials and Methods

This experiment was carried at Imogiri village, Imogiri sub-district (-7°54’52”, 110°22’50”), Bantul, Yogyakarta, in the dry season from May to August 2021. Plant spacing was *jajar legowo* 2:1 spacing (20 x 15 cm with 40 cm of legowo spacing). Research design was randomized block with a single factor of 4 treatments which was replicated 4 times. Treatments consist of: A = Inpari 32 HDB applied with insecticides, B = Inpari 42 GSR applied with insecticides, C = Inpari 32 HDB without insecticides application (Inpari 32 control), D = Inpari 42 GSR without insecticides application (Inpari 42 control). Insecticide with active ingredient spinetoram 120 g/l was applied to rice plant at day 40th with a concentration 1 ml l^{-1} and spray volume 250 l ha^{-1}. Triflumezopyrim 106 g/l was applied to rice plant at day 40th with concentration 1 ml l^{-1} and spray volume 250 l ha^{-1}. Application of pimetrozin 50% was conducted at day 50th with concentration 1 g l^{-1} and spray volume 250 l ha^{-1}. Population of BPH and natural enemies were recorded from 5 unit samples which placed in diagonal. One unit sample consist of six plants. Observation was conducted at day 1st to 10th after each insecticides application then continued at day 20th, 30th, and 40th after last insecticides application. Data of rice yield was confirmed by measuring grain weight based on Jajar Legowo Crop Cut Technique (*Teknik Ubinan Jajar Legowo*) [11].

2.2. Data Analysis
Analysis of Variance (ANOVA) was used to assess all data for the all data for the differences among treatments. Duncan Multiple Range Test Duncan (DMRT) (p=0.05) by the SPSS statistical package was (DMRT) (p=0.05) by the SPSS statistical package was used for was used for quantifying the means.

3. Results and Discussion
BPH, frequently termed green revolution pest in Asia tropics, is the main rice hassle [12]. Under favorable circumstances, BPH has a high reproduction potential in the area with intensive rice cultivation whereas one pair of BPH potent to the escalation of 400 million BPH in 85 days and resulting broad damage to more than 3 hectares rice crop area [12]. The use of sub-lethal insecticides doses generate resistance and resurgence of some insect pests, including BPH [13]. BPH control using synthetic pesticides is a major practice by farmers in South-East Asian countries, including the Philippines, Solomon Islands, India, Indonesia and Bangladesh [14]. Reducing natural enemies as a causal effect of intensive broad-spectrum insecticide application is one of the factors contributing to the BPH resurgence. Other factors contributing to the BPH resurgence are sub-lethal doses, rates and timing of pesticide application; reproduction stimulation following insecticide use; the application of insecticide-induced plant growth; methods of pesticide application; and rice varieties genetic resistance [15, 16]. Sub-lethal doses of the same compounds such as synthetic pyrethroids, carbamates and organophosphorus induced the resurgence of Delphacid [17]. BPH resurgence commonly occurs following insecticides use to susceptible rice varieties TN-1. At other site, biochemical changes at resistant varieties IR-36 due to insecticide application was not quite characteristically observed [18]. The application of pesticides in repetitive ways and spiraling increase (pesticide syndrome) reported might influenced the decrease of natural enemies, as well as insect pest resurgence and causing population outbreak of secondary pest outbreaks [19]. Three times spray of sub-lethal doses of deltamethrin and bifenthrin resulted higher BPH population, also increasing the feeding rate of BPH and reproductive rate of aphids. In addition, the organophosphorus compound (azinophos methyl) might improve nutrition and affect the hormones of reproduction of *Myzus persicae* [15, 20, 21].

The repetitive spray of different compounds of insecticides at a similar site of target might causing to the resistance emerge against insecticides in Vietnam, particularly at Red River Delta [22]. Unfortunately, information on insecticide usage by farmers is inadequate, and diminutive evidence is accessible on the efficacy of the insecticide to control BPH population dynamic in Yogyakarta. Therefore, to determine the insecticide application against BPH, we expected to define either the usage of insecticides and its impact on BPH, predators and neutral insects in irrigated rice fields in Yogyakarta Indonesia.

Based on research result, the BPH population in Inpari 32 HDB was significanty lower than in Inpari 42 GSR at age 40th after planting or on the day of first insecticides application (Figure 1). Then, on day 4th after insecticides application, the BPH population significantly decreased in Inpari 42 GSR and Inpari 32 HDB. The BPH population was higher in Inpari 42 control and Inari 32 HDB control than in Inpari 42, and Inpari 32 applied with insecticides. Interesting results were found on day 12th after the first insecticides application or day 2nd after the application of the second insecticides until day 50th. In contrast, the BPH population in all insecticide plants was significantly lower than BPH population in all control plants ($P<0.05$). In this research, farmers sprayed insecticides twice. The first application was on day 40th of planting age, with insecticide usage of spinetoram 120 g/l with concentration 1 ml l^{-1} and spray volume 250 l ha^{-1}. Another insecticide used triflumezopyrim 106 g/l, was applied to the rice plant on day 40th with a concentration 1 ml l^{-1} and spray volume 250 l ha^{-1}. Ten days after the first application, at day 50thof plant age, the second spray was conducted using pimetrozin 50% with a concentration of 1 g l^{-1} and spray volume of 250 l ha^{-1}. Research conducted by Nakata in Vietnam, farmers in the northern part apply insecticides using tanks of knapsack sprayers with spraying volumes of 12 to 18 l per 360 m^2 of farm size. They applied the mix of quite a few marketable products into one tank.

Nevertheless, most farmers applied a single package of insecticide in one tank. Still, they then adjusted the concentration of insecticide, which might be higher or lower than the instruction dosage depending on their input cost of the insecticide price or the incidence of diseases and occurrence of insects. The BPH (*Nilaparvata lugens* Stal.) population and WBPH-white-backed planthoppers (*Sogatella furcifera*) were influenced by active ingredients compound and crop seasons. Non-selective compounds lean towards decreasing either BPH or WBPH population, while the selective compound failed to reduce BPH population [23].

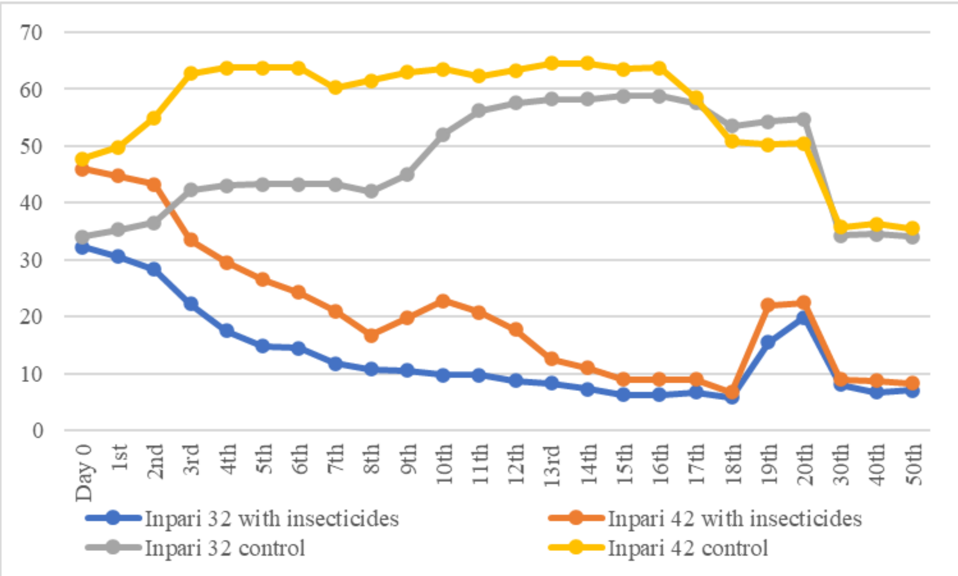

Figure 1. The population of BPH from day 0 (the day of first insecticides application) until day 50th

The world has long been concerned about how the unselective application of pesticides is the primary causal of the most important outbursts of insect pests [24]. One pest outburst was the occurrence of BPH across several Asian countries which grew rice during 2005 until 2012. Using insecticides which was broad - spectrum to control the pest insect affected natural enemies and boosted planthopper outbreaks. In Bangladesh, pesticide application to the rice field increased by 200% in 1997 to 500% in 2014, which might negatively impact the non-target and susceptible organisms and harm the environment [25, 26, 27, 28, 29]. Results showed that the spiders population in all plants was in average 50 per 30 plants at plant age 40 days or at the day of first insecticides application(Figure 2). Then at day 3rd after insecticides application, spiders population slightly decrease both in Inpari 42 GSR and Inpari 32 HDB. Extra decrease of spiders population was found at day 13th after first insecticides application or day 3rd after second insecticide application until day 30th, resulted in spiders population being distinctively lower in all plants sprayed with insecticides compared to control plants ($P<0.05$). In Vietnam, the spider's population increased the numbers of BPH [23]. According to [30], spiders significantly diverged across landscape categories and the bund width. A positive association was presented between landscape and predator diversities. Landscapes typically encircled with forest or fruit

Compactly habitats of perennial crops surround trees, and the whole area of rice and less annual crops increased the population of spiders. The perennial habitat grew closely, 10-30 meters to rice plots. In this landscape, small and narrow muddy canal flows between rice fields and agricultural roads,and some weeds grow along the canals. This landscape has a shallow sound irrigation system and a wider bund. The width of rice bunds separating smallholder plots is 25-30 cm—increasing bund width and resulting in spider populations. Wider bunds might have more significant numbers of weed species that might induce a higher population of spiders. However, there was no significant association between spider and weed species numbers at bunds [31].

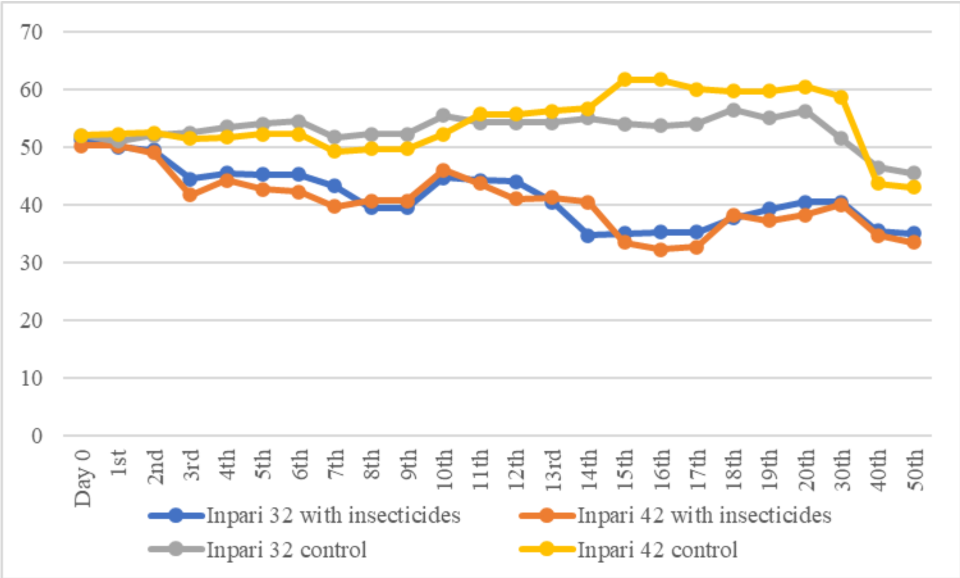

Figure 2. The population of spiders from day 0 (day of first insecticides application) until day 50^{th}

One of the predatory insects which potentially function as biological agents are members of familia Coccinellidae. Their imago and larvae stages are predators of aphids, planthoppers, and leafhoppers [32, 33]. They more actively prey at light times rather than in the dark [34]. In the case of *Synharmonia conglobata* Linnaeus, a member of Coccinelids preys 1.18 individuals WBPH per day at a light time while preys only 0.94 individuals/day in the dark period [35]. The attack effectiveness of predators is affected by environmental factors, including seasonal variation, humidity, light, rainfall, temperature, wind, host plant condition, and level of prey density [36, 37]. Our research showed that in all plants, both in insecticides application treatment and noninsecticides treatment (control), the population of Coccinelids was mostly constant with an average of 2 per 30 plants at the day of first insecticides application (plant age 40 days) until 59 days of plant age or day 19^{th} after first insecticides application (Figure 3). A significant increase in the Coccinelids population occurred from 60 until 90 days of plant age in plants without insecticides ($P<0.05$).

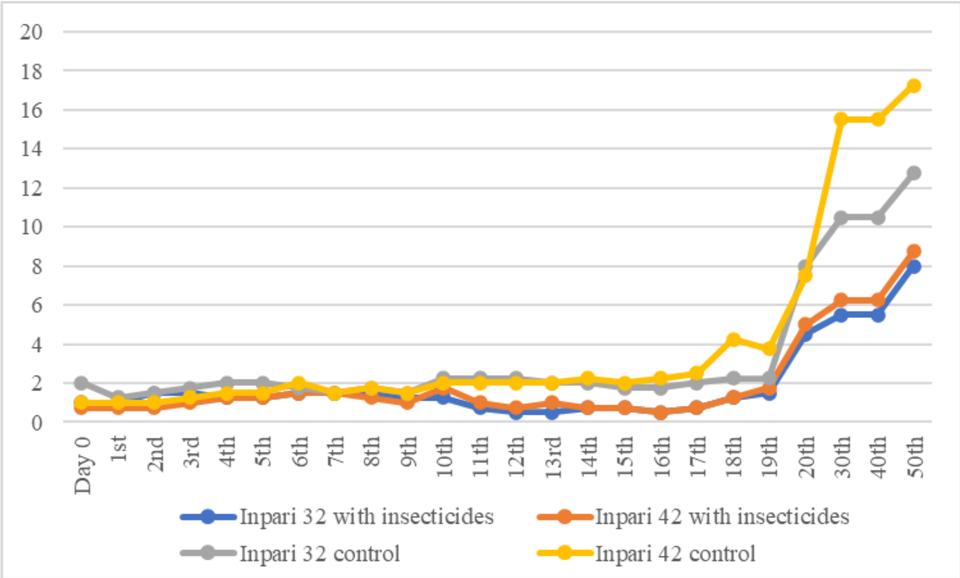

Figure 3. The population of *Coccinelids* from day 0 (the day of first insecticides application) until day 50th

At 40 days of plant age, the average population of *Cyrtorhinus* was 2-3 per 30 plants. Then, on day 1st after the insecticide application, their population decreased until day 17th (up to zero). It was shown that *Cyrtorhinus* was significantly affected (P<0.05) by insecticides in both at first application and the second application of insecticides, resulting in a substantially lower population than in control plants (Figure 4). However, in all plants, *the Cyrtorhinus population began to increase at 40 days of plant age (day 20th after the first insecticide application or day 10th after the second*) until 90 days of plant age. In Vietnam, the population of mirid bugs amplified the numbers of BPH and WBPH [23].

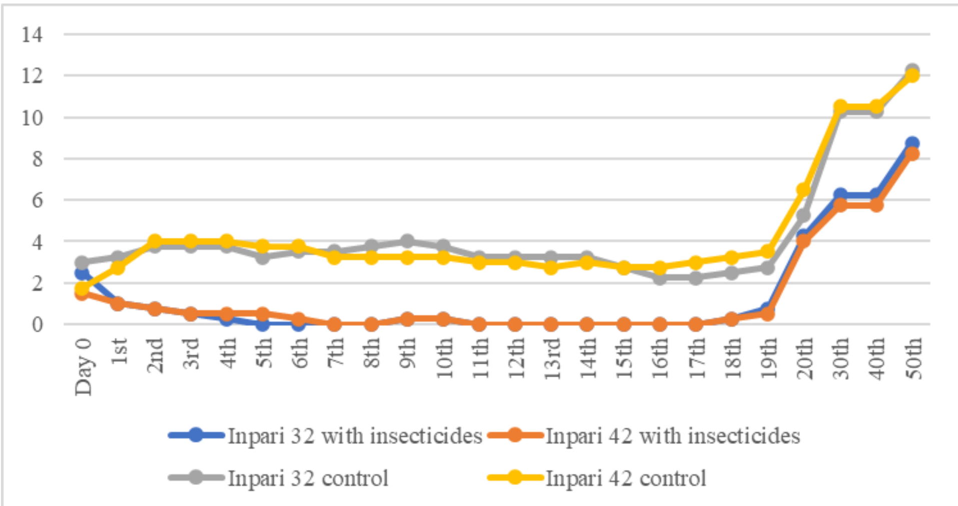

Figure 4. The population of *Cyrtorhinus* sp. from day 0 (day of first insecticides application) until day 50th

In all plants, both in insecticide application treatment as well as noninsecticides treatment (control), the population of Paederus, was typically relentless with 1-2 per 30 plants at the day of first insecticides application (plant age 40 days) until 59 days of plant age or day 19th after first insecticides application (Figure 5). However, significant population growth of Paederus occurred at 60 until 90 days of plant age in plants without insecticides compared to the insectides plants (P<0.05).

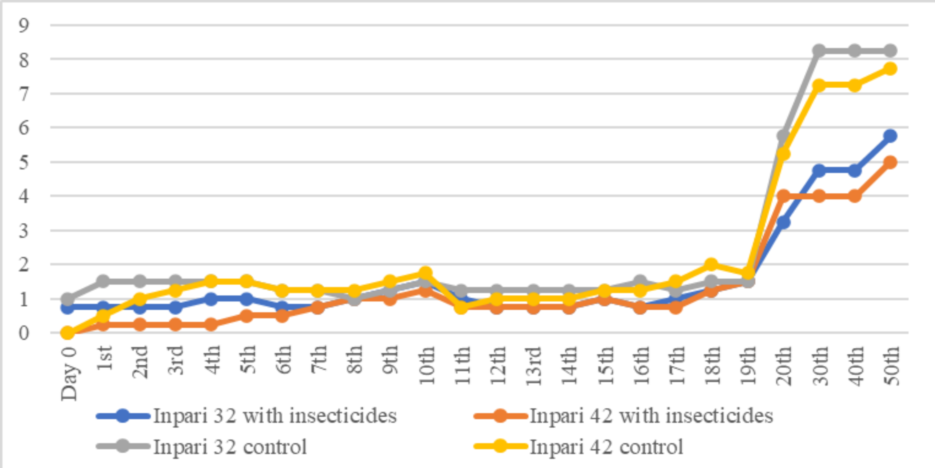

Figure 5. The population of *Paederus* sp. from day 0 (the day of first insecticides application) until day 50th

On day 0 of the first insecticide application (40 days of plant age), the average population of *Ophionea* was 0.5 – 1.5 per 30 plants (Figure 6). The population increased slightly even on day 1st after the insecticide application, except for Inpari 42 GSR, sprayed with spinetoram. However, on day 10th after the first insecticide application, the *Ophionea* population (2 – 2.5 per plant)was not different among treatments. On day 7th after the second insecticide application, the *Ophionea* population decreased to 0.5 per plant, then increased on day 20th after the first or day 10th after the second insecticide application. It was shown that *Ophionea* was significantly affected (P<0.05) by insecticides at first and second applications, resulting from a substantially lower population than in control plants. In addition, *Ophionea* population began to increase sharply at 60 days of plant age (day 20th after the first insecticide application or day 10th after the second insecticideapplication) until 90 days of plant age.

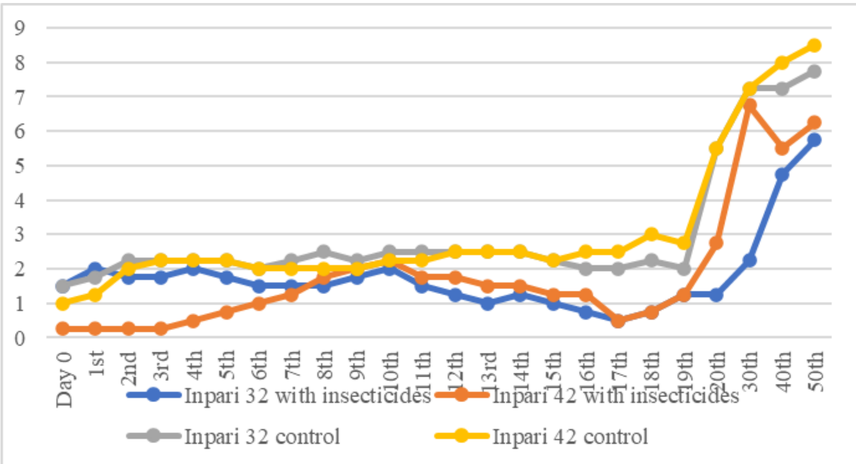

Figure 6. The population of *Ophionea* sp. from day 0 (day of first insecticides application) until day 50th

Besides predators as natural enemies, this research also observed neutral insects. It plays an essential role in a balance of an ecosystem and is a bioindicator of the injury of the ecosystem. The presence of neutral insects is vital in harmonizing the ecosystem and is a sign of a good or poisoned classified ecosystem. Nowadays, the use of bioindicators has been progressively significant through determining the association between biotic factors and the abiotic, particularly the pesticide application to the rice field. The differences in pesticide application are assumed to affect thepopulation dynamic of neutral insects [38]. The neutral insect population in Inpari 32 HDB was significantly less than in Inpari 42 GSR at 40 days of plant age or day zero (the day of first insecticidesapplication). Then at 48 days of plant age, the neutral insect population in plants sprayed with insecticides was significantly lower at day 8th after insecticides application ($P<0.05$). This trend occurred until day 59 of plant ages or day 19th after the first insecticide application. However, the population of neutral insects was not different among treatments at plant age 70 days or day 30th after applying the first insecticide (Figure 7).

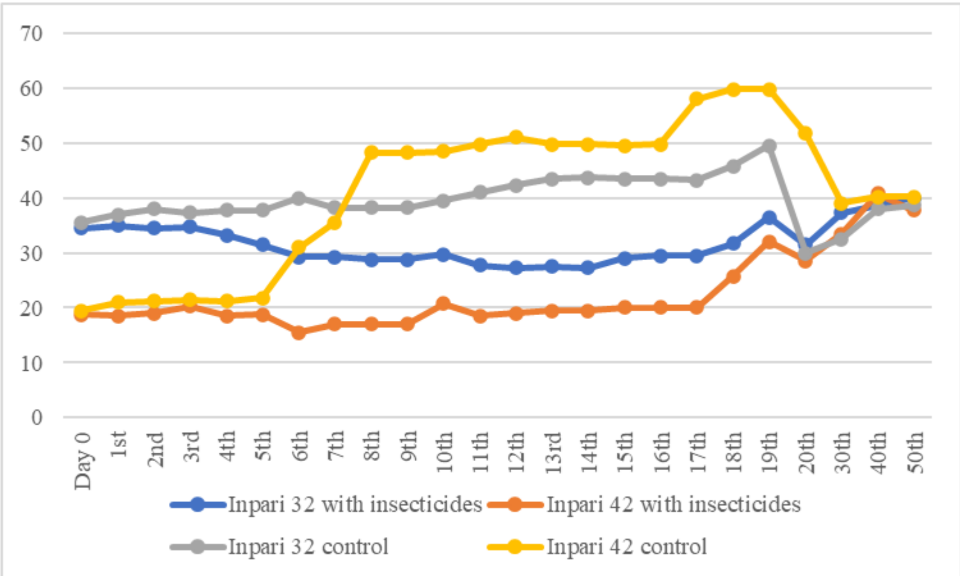

Figure 7. The population of neutral insects from day 0 (day of first insecticides application) until day 50th

4. Conclusion

The population of BPH was reduced from 30 -50 nymphs per 30 plants to 10 nymphs per 30 plants beginning on day 12th after pimetrozin 50% application or on day 2nd after spinetoram and triflumezopyrim insecticides application until day 50th. In contrast, the BPH population in all insecticide plants was significantly lower than in all control plants and did not increase until harvest. Predators such as Paederus sp and Coccinelids were unaffected by all insecticides such as spinetoram, triflumezopyrim, and pimetrozin, except *Ophionea* sp, Spiders, and *Cythorinus* sp., which significantly reduced the application of insecticide. However, their population recovered on day 30th after the first insecticide application. Within the fluctuated population of BPH, rice productivity of Inpari 32 HDB and Inpari 42 GSR applied with insecticides were 9.52 ton ha^{-1} and 10.60 ton ha^{-1}, while Inpari 32 HDB control and Inpari 42 GSR control 9.44 ton ha^{-1} and 10.72 ton ha^{-1}.

References

[1] Baehaki and Mejaya 2014 Wereng Cokelat sebagai Hama Global Bernilai Ekonomi Tinggi dan Strategi Pengendaliannya *Iptek Tanaman Pangan* **9** 1-12.
[2] Watanabe T and Kitagawa H 2000 Photosynthesis and translocation of assimilates in rice plants following phloem feeding by the planthopper *Nilaparvata lugens* (Homoptera: Delphacidae). *J. Econ. Entomol.* **93** 1192-1198.
[3] Watanabe T, Matsumura M, and Otuko A 2009 Recent occurrence of long-distance migratory planthopper and factors causing outbreaks in Japan. Situation of planthoppers in Asia. Planthoppers: a new threat to the intensive rice production systme's sustainability in Asia (IRRI publishing).
[4] Catindig JLA, Arida GS, Baehaki SE, Bentur JS, Cuong LQ, Norowi M, Rattanakarn W, Sriratanasak W, Xia J, and Lu Z 2009 Situation of the Planthoppers in Asia. In K Heong and B Hardy, Prc. Planthopper-New Threat to the Sustainability on the Intensive Rice Production System in Asia. International Rice Research Institute, Loas Banos, Philippines. p 191-220.
[5] Untung K and Trisyono YA http://www.faperta.ugm.ac.id/fokus/wereng_coklat_mengancam_swasembada_beras.php
[6] Chiu S 1979 Biological Cobtrol of the Brown Planthopper. Brown Planthopper: Threat to Rice Production in Asia. International Rice Research Institute. Philippines p 335 – 355.
[7] Siktiani C, Gunawan E, Mudjiono G, and Astuti LP 2015 Kelimpahan populasi wereng batang coklat *Nilaparvata lugens* Stal. (homoptera: delphacidae) dan laba-laba pada budidaya tanaman padi dengan penerapan pengendalian hama terpadu dan konvensional *Jurnal HPT* **3** 117-122.
[8] Endiyansah FR 2017 Pengaruh insektisida MIPC terhadap perkembangan populasi wereng batang coklat dan kompatibilitasnya dengan jamur Beauveria bassiana (Sarjana thesis, Universitas Brawijaya).
[9] Baehaki SE and Widiarta IN 2008 Hama wereng dan cara pengendaliannya pada tanaman padi. Hlm 347-384 **in** Padi 2, Inovasi Teknologi Produksi (AA Daradjat, Ed). LIPI Press.
[10] Baehaki SE, Iswanto EH, Munawar D and Sumaryono N 2016 Kecepatan dan hambatan rekolonisasi musuh alami setelah aplikasi insektisida di pertanaman padi *Jurnal Agrikultura* **27** 49-58.
[11] Indonesian Centre for Rice Research 2014 Teknik Ubinan Jajar Legowo (IAARD, Ministry of Agriculture publishing).
[12] Alam S and Karim ANMR 1986 Brown plant hopper situation and its management in Bangladesh. In: Proceedings of the workshop on experiences with modern rice cultivation in Bangladesh, 8-11 April 1984. BRRI, Gazipur, Bangladesh, pp: 2-18.
[13] Islam Z, Nahar MA, Hossain MA. Mia MAT and Ahmed HU 2001 Pest Management: Present status and future challenges In: Proceedings of the workshop on experiences with modern rice cultivation in Bangladesh, BRRI, Gazipur, Bangladesh, pp 97-106.
[14] Hague NMM, Haq HM and Karim ANMR 2002 *Pakistan of Biological Sciences* **5** 915-918.
[15] Chelliah S and Heinrichs EA 1984 Factors contributing to brown plant hopper resurgence In: Proceedings og the FAO/IRRI WorMhop ON Judicious and Efficient use of Insecticides on Rice, International Rice Research Institute, Los Banos, Laguna, Philippines, pp 105-115.
[16] Krishnaiah NV and Kalode MB 1987 Studies of resurgence in rice brown plant hopper *Nilaparvata lugens* (Stal) *Indian J. Entomol*. **49** 220-229.
[17] Chellish S and Ulhamasamy S 1986 Insecticide induced resurgence of insects pests of rice *Oryza* **23** 71-82.
[18] Buenaflor HG, Saxena RC, and Heinrichs EA 1981 Biochemical basis of insecticide-induced brown plant hopper resurgence *International Rice Research Institute Newsletter* **6** 13-14.
[19] Morse JG 1998 Agricultural implications of pesticide-induced hormesis of insects and mites *Human and Expl. Toxicol*. **17** 266-269.

[20] Chelliah S 1980 Influence of insecticide sprays on brown plant hopper resurgence *International Rice Research Institute Newletter* **5** 10-11.
[21] Kerns DL and Stewart SD 2000 Sub-lethal effects of insecticides on the intrinsic rate of increase of cotton aphid *Entomologia Experimentalis et Applicata* **94** 41-49.
[22] Sparks TC and Nauen R 2015 *Pestic. Biochem. Physiol*. **121** 122-128.
[23] Nakata MM, Chung NH and Kobori Y 2019 Insecticide application and its effect on the density of rice planthoppers, Nilaparvata lugens and Sogatella furcifera, in paddy fields in the Red River Delta, Vietnam *J. Pestic. Sci.* **44** 129-135 doi: 10.1584/jpestics.D18-080.
[24] Stern V, Smith R, Van den Bosch R. Hagen 1959 The integration of chemical and biological control of the spotted alfalfa aphid: the integrated control concept. *Hilgardia* **29** 81-101.
[25] Bangladesh Crop Protection Association: List of registered agricultural, Bio and Public Health Pesticide in Bangladesh 2013 Accessed 20 July 2022.
[26] Ali M, Bari M, Ahmed N, Kabir M, Arifin S, Zaman M, and Willers J 2017 Rice production without insecticides in smallholder farmers' field. Front Environ Sci. https://doi.org/10.3389/fenvs.2017.00016.
[27] Ahmed N, Englund JE, Ahman I, Lieberg M, and Johansson E 2011 Perception of pesticide use by farmers and neighbors in two peri urban areas *Sci of the total Env* **412** 77-86.
[28] Ahmed N, Islam Z, Hasan M, and Kamal N 2002 Effect of some commonly used insecticides on yellow stem borer egg parasitoids in Bangladesh *Ban J of Entom*. **12** 37-46.
[29] Travisi CM, Nijkamp P, and Vindigni G 2006 Pesticide risk evaluation in empirical economics: A comparative approach *Ecol Econ*. **56** 455 – 474.
[30] Ali MP, Kabir MMM, Haque SS, Afrin S, Ahmed N, Pittendrigh B and Qin X 2020 Surrounding landscape influences the abundance of insect predators in rice field BMC *Zoology* **5** 8-20 https://doi.org/10.1186/s40850-020-00059-1.
[31] Sigsgaard L 2000 Early season natural biological control of insect pests in rice by spiders and some factors in the management of the cropping system that may affect this control. Presented at the European Arachnology.
[32] Baehaki SE 1992 Berbagai hama serangga tanaman padi. Penerbit Angkasa. Bandung.
[33] Pracaya 2005 Hama dan Penyakit tanaman. Penerbit swadaya. Jakarta.
[34] Simanjuntak H 2002 Musuh alami hama dan penyakit tanaman lada. Direktur perlindungan perkebunan Jakarta.
[35] Sjakoer NAA 2010 Mortalitas hama wereng punggung putih setelah dimangsa oleh serangga predator (pengamatan visualisasi di green house) *El-Hayah* **1** 35-39.
[36] Hufaker CB and Messenger PS 1989 Theory and practice of biological control (terjemahan). Universitas Indonesia Press. Jakarta.
[37] Hidayat P and Sartiani D 2008 Hama (Serangga) dan lingkungannya. http://ipb.ac.id/phidayat/perlintan.
[38] Herdiawan WS, Nurkomar I, and Trisnawati DW 2020 Biodiversity of detritivores, pollinators and neutral insects on surjan and conventional rice filed ecosystems. Advances in Engineering Research, volume 199 Proceedings og=f the 4th International Conference on Sustainable Innovation 2020 – Technology, Enggineering and Agriculture (ICoSITEA 2020).

Acknowledgement
We appreciate the Indonesian Agency for Agricultural Research and Development (IAARD) for funding this research. A field experiment was conducted by collaboration with students of UPN Pembangunan University (Sandy Setyawan Kertagosa, Dzaky Razan Nur Asyam, Akhmad Rudy Fikri Setiyawan), the extension team of IAARD and Dinas Pertanian Bantul team as follow: Suradal, Evy Pujiastuti, Umi Pujiastuti, Gani, Amjad, and Lukito. Appreciation is also delivered to the Farmer Group Sedyo Maju (Naryoto) in Imogiri Village Bantul for the great support during the field experiment.