ABSTRACT

The brown plant hopper (BPH) is a major pest of rice and as a vector of Rice ragged stunt virus (RRSV) and Rice grassy stunt virus (RGSV). Currently, numerous rice yellow stunt disease symptoms are found in the field that caused by the single and simultaneous infection of these two viruses. Brown plant hopper population correlate with the incidence and severity of the disease. Misuse of insecticides, would cause of BPH resistances to imidacloprid. This study aimed to investigate the ability of BPH imidacloprid-resistant and susceptible to transmit of rice yellow stunt disease on rice plants. The variables tested were the acquisition period, inoculation period, number of infesting BPH, and lifespans of the viruliferous BPH that used in this research. Experiments were set as separated Completely Randomized Design with 10 replications for each treatment within an experiment. The results showed that both resistant and susceptible BPH to imidacloprid was able to transmit the virus to healthy plants. The acquisition and inoculation period test showed the BPH could transmit the virus with the shortest acquisition time for 30 minutes followed 24 hours of inoculation, as well as the acquisition time of 10 days with the shortest inoculation time for 30 minutes. Based on the incubation time, symptoms variation, and disease severity, susceptible BPH were more effective in transmitting rice yellow stunt disease than imidacloprid-resistant BPH. Single imidacloprid-resistant or susceptible BPH was proven able to transmit rice yellow stunt disease to healthy plants during its lifespan. Lifespans BPH viruliferous of imidacloprid-resistant were shorter than susceptible, which was 16 days for resistant BPH and 21 days for susceptible BPH.

Keywords: brown plant hopper; imidacloprid resistant; virus transmission; yellow stunt disease

INTRODUCTION

Brown plant hopper (Nilaparvata lugens Stall) (BPH) is a major pest in several rice production centers around Indonesia and is able to threat national self-sufficiency of rice (Untung & Trisyono 2009). This is a devastating pest due to its ability to cause puso (harvest failure). Besides being pest on rice, BPH are also able to transmit rice grassy stunt virus (RGSV) and rice ragged stunt virus (RRSV) (Cabautan et al., 2009). Both viruses are persistently transmitted by BPH (Ling, 1977; Hibino, 1996). The occurrence of RRSV and RGSV in Indonesia has been reported since 1977. In 1977, RRSV was found with high incidence in Indonesia and Vietnam (Du et al., 2007). Currently, RRSV has been reported in several rice areas in Java and Bali (Kusuma et al., 2018). RGSV was first reported in Philippines at 1963 (Rivera et al., 1966). This disease later spreaded to South Asia, China, Japan, and Taiwan (Hibino, 1996). In Indonesia during 1970–1977, high incidence of RGSV was occured (Hibino, 1989). In the last ten years, especially in Java and Bali, outbreaks of BPH have been followed by yellow stunt disease with various symptoms. The most found symptoms was yellow stunt with the main symptoms are for plants to be stunted, posses leaf malformation, and turning yellow (Dini et al., 2015; Kusuma et al., 2018; Helina et al., 2018; 2019).
In Indonesia, continuous monoculture of rice is always found in areas where established irrigation system exists. An example of these areas is the District of Bantul, Yogyakarta. Based on observation in 2013, high incidence of yellow stunt symptoms were found in areas where BPH outbreaks and harvest failure occurred in the previous seasons. Direktorat Perlindungan Tanaman Pangan (2011) reported that the area of BPH attacks was almost double the area attacked in the previous year of 173,890 ha with damage of 22,613 ha.

This disease is caused by the infections of RGSV and RRSV (Helina et al., 2018; 2019). In these areas, farmers heavily rely on continuous use of the same active ingredient, one of these active ingredients was imidacloprid. This practice increases the risk of BPH populations to grow resistances to currently available insecticides. BPH are known to be resistant to 29 active ingredients around the world (Sparks & Nauen, 2015). China, India, Indonesia, and Thailand have reported BPH resistances against insecticides (Catindig et al., 2009). Cox (2001) reported that imidacloprid was first used in several areas around Indonesia at 1994. In Banyumas, population outbreaks of resistan BPH due to continuous use of imidacloprid have been reported (Londingkene et al., 2016).

Continuous use of imidacloprid can increase resistant ratio (RR) of the next generation and has already been reported in Indonesia. Increases have been reported in Karawang by 108.1 folds, 12.7 folds in Subang (Surahman et al., 2016), and 7.0 folds in Klaten (Baehaki, 2011). Resistance ratio against imidacloprid have been reported to increase to the next generation. Diptaningsari et al. (2019) reported RR increase of 5 generations from Banyumas by 46.2 folds to 150.39 by the fifth generation. The same results occurred in BPH from Karawang where RR increase by 13.5 folds in the 6th generation (Iswanto et al., 2019). Resistance inheritances is autosomal, epigenetic not completely dominant, and not stabil (Diptaningsari et al., 2019; 2020). Resistance monitoring is an essential effort to understand population susceptibility to several active ingredients as a management strategy to prevent insecticide resistances within pest populations (Zhang et al., 2016).

Resistance mechanisms of insects against insecticides involves overexpression or mutations of enzymes for detoxification genes and amino acid of targeted genes (Sparks & Nauen, 2015). Baehaki et al. (2016) reported that BPH from several areas in Java had different levels of resistance to the insecticides imidacloprid, etiprol, tiametoxam, fipronil, BMPC, MIPC, buprofezin, sipermethrin and sihalothrin. Based on previous findings, it is necessary to determine the differences of yellow stunt transmission between susceptible and imidacloprid-resistant BPH populations. This study aimed to investigate the ability BPH imidacloprid-resistant and susceptible to transmit yellow stunt disease on rice plants. The research was done on January–March 2018 at Laboratory and a greenhouse at sub Laboratory of Plant Virology, Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada.

**MATERIALS AND METHODS**

**BPH and Inoculum Source**

Rice plants affected by double infections in Bantul were taken as inoculum sources. Double infection was showed with the symptom of stunted plant, turned yellow in the tip of the leaf, there was none of panicles, grow upright, ragged, gall and twisted tip leaf especially in the younger part (Helina et al., 2019). Experiments were conducted at the Virology Laboratory, Faculty of Agriculture, Universitas Gadjah Mada. Susceptible and imidacloprid-resistant BPH populations were obtained from the Laboratory of Pest Management, Toxicology Division, Faculty of Agriculture, Universitas Gadjah Mada.

**Brown Plant Hopper Rearing**

BPH taken from the field were reared on rice plants var. Ciherang aged 2 weeks in plastic containers with tops closed with mesh cloth after reaching 3rd instars. BPH were placed on inoculum sources for virus acquisition. Infectious BPH were then moved to healthy plant using aspirator. Inoculated plants were then transplanted to plastic trays containing growing media. Observations were done every 2 days.
Rice Yellow Stunt Disease Transmission Using Imidacloprid-Resistant and Susceptible Brown Planthoppers

For experiment the acquisition period treatments were conducted using imidacloprid-resistant and susceptible BPH to ingest the virus from diseased plants for 3, 6, 12, 24 hours, and 3, 5, 7, 10 days. The viruliferous BPH were then inoculated on healthy plants for 24 hours. For experiment the inoculation period treatment were conducted using BPH for ingest the virus for 10 days on diseased plants. Viruliferous BPH and then transferred to the healthy plants for 30 minutes, 60 minutes, 3, 6, 12 and 24 hours to inoculate the virus. For experiment the number of BPH were done after acquisition on diseased plant for 10 days, the viruliferous of BPH was transferred to healthy plants with the number of 1, 2, 3, and 5 respectively for each treatment and allowed to inoculate the healthy plant for 24 hours. The virus retention experiment used susceptible and imidacloprid-resistant BPH populations were let to feed on diseased plant for 10 days to acquisition of the virus. One viruliferous BPH then was transferred on to a healthy plant for 24 hours to inoculate the virus. After that, the same of BPH was moved to a new healthy plant and let to transmit the virus again for the next 24 hours. This was repeated until the BPH was died. Inoculated plants were transplanted to growing media on trays and incubated in a greenhouse. Experiments were set as separated Completely Randomized Design with 10 replications for each treatment within an experiment.

Observations

Incubation time, symptoms variations, incidence, and disease severity were observed in this experiment. Observations were done weekly for 4 weeks after treatments. Severity and incidences were calculated using the formula from Zadoks and Schein (1979), with slight modifications. Disease severity were scored for each plant (Table 1). Based on the scores were processed to calculated disease severity using the following formula:

\[
\text{Disease severity} = \frac{m \times v}{N \times Z} \times 100\% 
\]

Data Analysis

Data were analyzed using ANOVA in R. Treatments that showed significant differences based on their P-value were tested using DMRT post-hoc test at \( \alpha = 5\% \).

RESULTS AND DISCUSSION

Effect Acquisition Feeding Period of Susceptible and Imidacloprid-Resistant BPH to Transmission of Rice Yellow Stunt Disease

Experiment of the acquisition period of resistant and susceptible BPH, showed the incubation period were not difference, but based on the incidence and intensity of disease, susceptible BPH was more efficient to transmit the virus (Table 2) Susceptible BPH could more ingest the virus on inoculum source than the resistant. In resistant BPH maybe occurring physiological change caused by imidacloprid compound.

Acquisition feeding period of imidacloprid-resistant and susceptible BPH on infected plants for 3 hours and inoculation for 24 hours were able to cause symptoms (Table 2). The same data was reported by Morinaka et al. (1983), but another researcher also reported the shorter acquisition time with 2 hours and 1 hours inoculation time could transmit the disease (Chen & Chiu, 1981). The longer of vector acquisition periods in plants, the virus concentration in the vector becomes higher.

| Score | Symptoms                                      |
|-------|-----------------------------------------------|
| 0     | Healthy plants                                 |
| 1     | Leaves were yellow or pale green               |
| 2     | Leaves were yellow or pale green; small, ragged, twisted tips, and gall appear |
| 3     | Leaves were yellow or pale green, small, ragged, twisted tips, gall appear, excessive tillering |
| 4     | twisted tips, gall appear, excessive tillering, and stunted |

Table 1. Stunt symptom scoring for rice (Kusumaningrum, 2018)
Based on the data showed BPH were able to transmit yellow stunt virus to rice plant in a short time. The length of acquisition was depend on related to preference of the BPH on its host. Ciherang was reported as a preference host for BPH (Suprihanto et al., 2016). As a preference host, the BPH could suck nutrients as well as the virus in the host directly without needed for orientation time, so the condition is very effective as a vector.

Shorter acquisition time will increase the speed of rice yellow stunt disease dispersion. BPH preferences also depend on the host condition. BPH are more attracted to infected plants than healthy ones due to the ability of infected plants to emit attractive volatiles (Wang et al., 2018).

On various treatments, it appears that resistant BPH has a longer incubation period than susceptible ones. It was closely related to viral titer in its insect. Feeding ability on resistant BPH would be decrease because of their fitness. Iswanto et al. (2019) and Liu and Han (2006) reported that imidacloprid-resistant BPH fitness decrease drastically compared to susceptible BPH. High viral titer will affect the incubation period and the severity of the symptoms severity.

Length of acquisition period between BPH imidacloprid-resistant and susceptible would affect disease severity (Table 3). Longer acquisition time caused more severe symptoms and shortens the time for the symptoms to appear (Figure 1 and 2).

### Table 2. Effect of acquisition period on yellow stunt symptoms after 4 weeks since innoculation

| Resistant Status          | Acquisition Period | Incubation time (days) | Symptom Variations                                      |
|---------------------------|--------------------|------------------------|----------------------------------------------------------|
| Imidacloprid-resistant    | 3 hours            | 12.25                  | Yellow and shrinked leaves                               |
|                           | 6 hours            | 12                     | Yellow and shrinked leaves                               |
|                           | 12 hours           | 11.7                   | Yellow and shrinked leaves                               |
|                           | 24 hours           | 11.6                   | Leaves are yellow, shrinked, and ragged on their perimeters |
|                           | 3 days             | 11.1                   | Leaves are yellow, shrinked, and ragged on their perimeters |
|                           | 5 days             | 10.9                   | Leaves are yellow, shrinked, and ragged on their perimeters |
|                           | 7 days             | 10.7                   | Leaves are yellow and shrinked, tillers are fanning, and young leaves are ragged |
|                           | 10 days            | 10.2                   | Leaves are yellow and shrinked, tillers are fanning, gall appear at leaf bases, and young leaves are ragged |
| Susceptible               | 3 hours            | 12.12                  | Yellow and shrinked leaves                               |
|                           | 6 hours            | 11.1                   | Yellow and shrinked leaves                               |
|                           | 12 hours           | 11.1                   | Yellow and shrinked leaves                               |
|                           | 24 hours           | 10.9                   | Leaves are yellow, shrinked, and ragged on their perimeters |
|                           | 3 days             | 10.8                   | Leaves are yellow, shrinked, and ragged on their perimeters |
|                           | 5 days             | 10.6                   | Leaves are yellow, shrinked, and ragged on their perimeters, fanning on tillers |
|                           | 7 days             | 10.6                   | Leaves are yellow, shrinked, and ragged on their perimeters, fanning on tillers |
|                           | 10 days            | 10                     | Leaves are yellow, shrinked, and ragged on their perimeters, fanning on tillers |

### Table 3. Effect of acquisition period on yellow stunt severity

| Resistant Status          | 3 hours | 6 hours | 12 hours | 24 hours | 3 days | 5 days | 7 days | 10 days | Average |
|---------------------------|---------|---------|----------|----------|--------|--------|--------|---------|---------|
| Imidacloprid-resistant    | 1*      | 1.1     | 1.1      | 1.4      | 1.3    | 1.6    | 1.6    | 1.8      | 1.35b    |
| Susceptible               | 1.4     | 1.4     | 1.6      | 1.6      | 1.4    | 1.8    | 1.9    | 1.9      | 1.62a    |
| Average                   | 1.2d    | 1.25d   | 1.35cd   | 1.45bcd  | 1.35d  | 1.7abc | 1.75ab | 1.85a    |

*: Numbers followed by different letters in the same row or column were significantly different based on a DMRT post-hoc test at α=0.05

so faster to become viruliferus (Hibino et al., 1977). Based on the data showed BPH were able to transmit yellow stunt virus to rice plant in a short time. The length of acquisition was depend on related to preference of the BPH on its host. Ciherang was reported as a preference host for BPH (Suprihanto et al., 2016). As a preference host, the BPH could suck nutrients as well as the virus in the host directly without needed for orientation time, so the condition is very effective as a vector.

On various treatments, it appears that resistant BPH has a longer incubation period than susceptible ones. It was closely related to viral titer in its insect. Feeding ability on resistant BPH would be decrease because of their fitness. Iswanto et al. (2019) and Liu and Han (2006) reported that imidacloprid-resistant BPH fitness decrease drastically compared to susceptible BPH. High viral titer will affect the incubation period and the severity of the symptoms severity.

Length of acquisition period between BPH imidacloprid-resistant and susceptible would affect disease severity (Table 3). Longer acquisition time caused more severe symptoms and shortens the time for the symptoms to appear (Figure 1 and 2).
Acquisition time of 5 days can effectively transmit virus and was not significantly different from other treatments. Virus’s titer inside plants affect incubation time and the severity of symptoms. This was shown in our results (Figure 3).

**Effects of Inoculation Time of Susceptible and Imidacloprid-Resistant BPH on Transmission of Rice Yellow Stunt Disease Virus**

Inoculation time of 30 minutes was already able to cause imidacloprid-resistant BPH to be able to transmit virus. Susceptible BPH were more effective in transmitting virus. Disease incidence and severity increased as inoculation periods became longer (Table 4).

At 2 weeks after inoculation, susceptible BPH caused 60–100% disease incidence and 15–25% disease severity, while imidacloprid-resistant BPH caused disease incidence of 40–70 % and disease severity of 10–18%. Longer inoculation time increases the concentration of viruses transmitted into plants. Based on these results, both imidacloprid-resistant and susceptible BPH were potential vectors due to
their ability to transmit virus after inoculation time for 30 minutes (Table 4). Shorter inoculation periods have been reported by Hashim and Ang (1984) where BPH were able to inoculate RRSV to healthy plants within 10 minutes. The data was important for the epidemiology studies of yellow stunt disease that caused by the mixed of RGSV and RRSV.

The longer the inoculation periods, the higher the disease severity (Table 5). Disease severity caused by susceptible BPH were significant higher compared to imidacloprid-resistant BPH. This may be due to the ability of susceptible BPH to ingest more nutrition and virus from inoculum sources. Iswanto et al. (2019) and Liu and Han (2006) reported that imidacloprid-resistant BPH fitness decrease drastically compared to susceptible BPH. In contrast to BPH which is not susceptible, the time required for inoculation is longer. Helina et al. (2018) reported double infection of RGSV and RRSV that attacked Cihetang variety had incubation 10 days after inoculation (DAI) meanwhile for Situ Bagendit variety was 14 DAI. Disease severity increased as inoculation periods were longer (Figure 4 and 5).

![Figure 3. Variation of disease symptoms on 28 days after inoculation; (A). Twisted leaf tips and bases after BPH infestation; (B). Ragged leaf perimeters and galls](image)

| Table 4. Effect of inoculation period on the symptoms yellow stunt at 4 weeks after inoculation |
| Resistant Status | Inoculation Period | Incubation Period (days) | Symptoms Variation |
|------------------|--------------------|--------------------------|-------------------|
| Imidacloprid-resistant | 30 minutes | 12.87 | Yellow and shrank leaves |
| | 60 minutes | 11.62 | Yellow and shrank leaves |
| | 3 hours | 11.7 | Yellow and shrank leaves |
| | 6 hours | 11.6 | Yellow and shrank leaves |
| | 12 hours | 10.7 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
| | 24 hours | 10.5 | Leaves are yellow and shrank, fanning tillers, and ragged leaves, gall appear at leaf bases |
| Susceptible | 30 minutes | 12.9 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
| | 60 minutes | 12.2 | Yellow and shrank leaves |
| | 3 hours | 10.6 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
| | 6 hours | 10.2 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
| | 12 hours | 10.8 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
| | 24 hours | 10.1 | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
Table 5. Effect of inoculation period on yellow stunt severity

| Resistant Status    | Disease Severity (%) at Inoculation Period | Average |
|---------------------|-------------------------------------------|---------|
|                     | 30 minutes | 60 minutes | 3 hours | 6 hours | 12 hours | 24 hours |         |
| Imidacloprid-resistant | 1*        | 1          | 1.3     | 1.3     | 1.7      | 1.8      | 1.35b   |
| Susceptible         | 1.8       | 1.8        | 1.9     | 1.7     | 1.8      | 1.9      | 1.8 a   |
| Average             | 1.4c      | 1.4c       | 1.6abc  | 1.5bc   | 1.75ab   | 1.85a    |         |

*: Numbers followed by different letters in the same row or column were significantly different based on a DMRT post-hoc test at α=0.05

Figure 4. **Rice stunt yellow symptoms on 28 days after inoculation; (A). Inoculation treatment for 24 hours of imidacloprid-resistant brown plant hoppers; (B). Inoculation treatment for 30 minutes of imidacloprid-resistant plant hoppers; (C). Control

** the height and vigour of plants showed difference

Figure 5. **Yellow stunt symptoms on 28 days after inoculation; (A). Inoculation treatment of 24 hours of susceptible brown plant hoppers; (B). Inoculation treatment for 30 minutes of imidacloprid-susceptible plant hoppers; (C). Control

** the height and vigour of plants showed difference
Effect of the Number of BPH Imidacloprid-Resistant and Susceptible to Rice Yellow Stunt Disease Transmission

Symptoms appeared sooner as the number of BPH increased (Table 6) due to the increase of viruses transmitted into plants. It is noteworthy, that even one BPH was enough to transmit this virus. This challenge the economic thresholds used when BPH are considered as pest and demonstrates the merit of different threshold when they are considered as vectors and inoculum sources exist in the field.

One susceptible BPH could be more effective in transmitting virus than imidacloprid-resistant BPH based on disease incidence and severity of the disease (Table 7). Although by single imidacloprid-resistant or susceptible BPH was enough to transmit virus, the increase of BPH numbers increased severity of symptoms on plants (Figure 6 and 7). Helina et al. (2018) also reported that 1–2 BPH were able to transmit RGSV or RRSV in field tests, but the incubation period for each plant was different depending on plant resistance and their virulences.

The number of BPH significantly affected the incidence and severity of the disease even though their resistance state had not effects. At high numbers, BPH may cause hopperburns and damage plants, meanwhile it only requires one BPH to transmit the virus. Therefore, monitoring of BPH and yellow stunt inoculums in the fields is essential.

Effect of Viruliferous BPH Imidacloprid-Resistant and Susceptible for its Lifespans

Imidacloprid-resistant BPH had shorter lifespans than susceptible BPH (Figure 8). Faster mortality occurred at imidacloprid-resistant BPH at day at 2–10 compared to susceptible of BPH that died at day 10–12. Observations on days 10–12, the number of resistant and susceptible BPHs that survived was still 60%, but on the following day, the number of resistant and sensitive BPH that died was more numerous and faster than those with sensitive ones. The number of resistant BPH that died reached 100% on the 16th day while sensitive BPH could survive up to 21 days. This may be due to physiological factors and cytological effects of BPH due to the effects of insecticides. In resistant BPH, there will be a decrease in fitness, survival, fecundity, number of eggs and their life span (Liu et al., 2012; Iswanto et al., 2019). As previously mentioned, fitness of resistant BPH are lower than susceptible ones. However, it needed to be aware that resistant BPH are still able to reproduce in the field and cause damage (Matsumura et al., 2008).

| Resistant Status       | Number of BPH | Incubation Period (days) | Symptoms Variation                                      |
|------------------------|----------------|--------------------------|--------------------------------------------------------|
| Imidacloprid-resistant | 1              | 9.8                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 2              | 9.9                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 3              | 7.3                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 5              | 6.1                      | Leaves are yellow and shrank, stunted plants            |
| Susceptible            | 1              | 9.4                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 2              | 9.4                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 3              | 7.1                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |
|                        | 5              | 6.3                      | Leaves are yellow and shrank, fanning tillers, and ragged leaves |

Table 6. Effect of brown plant hopper (BPH) numbers to yellow stunt symptoms at 4 weeks

| Resistant Status       | BPH numbers | Average |
|------------------------|-------------|---------|
| Imidacloprid-resistant | 1.8*        | 2.25    |
|                        | 1.9         | 2.225   |
| Susceptible            | 1.85b       |         |
|                        | 2.00b       |         |

*: Numbers followed by different letters in the same row or column were significantly different based on a DMRT post-hoc test at α=0.05

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Figure 6. **Yellow stunt symptoms on 28 days after inoculation; (A). treated with 5 imidacloprid-resistant individuals; (B). 3 imidacloprid-resistant individuals; (C). treated with 2 imidacloprid-resistant individuals; (D). treated with 1 imidacloprid-resistant individuals**. The height and vigour of plants showed difference.

Figure 7. **Yellow stunt symptoms on 28 days after inoculation; (A). treated with 5 susceptible individuals; (B). treated with 3 susceptible individuals; (C). treated with 2 imidacloprid-susceptible individuals; (D). treated with 1 imidacloprid-susceptible individuals**. The height and vigour of plants showed difference.

Figure 8. Lifespan of 3rd instar of imidacloprid susceptible and resistant brown plant hopper (BPH)
Density population of BPH in the field needs to be aware in relation to the role of BPH as a pest and as a vector. Even though the BPH population in the field was low, if there were some rice yellow stunt disease symptom, weeds, and infected plant debris in the field, it would be as an inoculum source of the disease. BPH would more attracted on diseased plant than on healthy one for breeding site and also feeding area in the field. The condition could increase the mobility of BPH in the field and will simultaneously transmit the disease.

CONCLUSION

Based on incubation period, symptom variation and disease severity, susceptible BPH were more effective in transmitting yellow stunt disease to healthy plants compared to imidacloprid-resistant individuals. The results showed that both resistant and susceptible BPH to imidacloprid was able to transmit the virus to healthy plants. The acquisition period and inoculation period test showed the BPH could transmit the virus with the shortest acquisition time for 30 minutes followed 24 hours of inoculation, as well as the acquisition time of 10 days with the shortest inoculation time for 30 minutes. Single BPH susceptible or imidacloprid-resistant BPH were able to transmit virus to healthy plants. Lifespans of viruliferous BPH imidacloprid-resistant BPH were shorter than susceptible BPH.

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LITERATURE CITED

Baehaki, S.E., Iswanto E.H., & Munawar, D. (2016). Resistensi Wereng Coklat terhadap Insektisida yang Beredar di Sentra Produksi Padi. Jurnal Penelitian Pertanian Tanaman Pangan, 35(2), 99–107. https://doi.org/10.21082/jpnppt.v35n2.2016.p99-108

Baehaki, S.E. (2011). Strategi Fundamental Pengendalian Hama Wereng Batang Coklat dalam Pengamanan Produksi Padi Nasional. Pengembangan Inovasi Pertanian, 4(1), 63–75.

Cabautan, P.Q., Cabunagan, R.C., & Choi, I.R. (2009). Rice Viruses Transmitted by the Brown Planthopper Nilaparvata lugens Stal. In K.L. Heong & B. Hardy (Eds.), Planthoppers: New Threats to the Sustainability of Intensive Rice Production Systems in Asia (pp. 357–368). Los Baños, Phillipines: International Rice Research Institute.

Catindig, J.L.A., Arida, G.S., Baehaki, S.E., Bentur, J.S., Cuong, L.Q., Norowi, M., Rattanakarn, W., Siriratnasak, W., Xia, J., & Lu, Z. (2009). Situation of Planthoppers in Asia. In K. Heong & B. Hardy (Eds.), Planthopper-New Threat to the Sustainability on Intensive Rice Production System in Asia. (pp. 191–220). Los Baños, Phillipines: International Rice Research Institute.

Chen, C.C. & Chiu, R.J. (1981). Rice Ragged Stunt and its Effect on the Growth of the Rice Plant. Plant Protection Bulletin, 23(2), 67–75. Abstract.

Cox, C. (2001). Imidacloprid. Journal of Pesticide Reform, 21(1), 15–21.

Dini, A.F.B., Winasa, I.W., & Hidayat, S.H. (2015). Identifikasi Virus Penyebab Penyakit Kerdil pada Tanaman Padi di Sukamandi, Jawa Barat. Jurnal Fitopatologi Indonesia, 11(6), 205–210. https://doi.org/10.14692/jffi.11.6.205

Diptaningsari, D., Trisyono, Y.A., Purwantoro, A., & Wijonarko, A. (2019). Inheritance and Realized Heritability of Resistance to Imidacloprid in the Brown Planthopper, Nilaparvata lugens (Hemiptera: Delphacidae), from Indonesia. Journal of Economic Entomology, 112(4), 1831–1837. https://doi.org/10.1093/jee/toz090

Diptaningsari, D., Trisyono, Y.A., Purwantoro, A., & Wijonarko, A. (2020). Stability of Resistance to Imidacloprid in the Brown Planthopper (Nilaparvata lugens Stål.) from Banyumas, Central Java. Jurnal Perlindungan Tanaman Indonesia, 24(1), 61–67. https://doi.org/10.22146/jpti.43954

Direktorat Perlindungan Tanaman Pangan. (2011). Data Serangan BPH Januari sampai Desember 2011 di Provinsi di Pulau Jawa. Jakarta, Indonesia: Direktorat Jendral Tanaman Pangan Kementerian Pertanian.
Du, P.V., Cabunagan, R.C., Cabauatan, P.Q., Choi, H.S., Choi, I.R., Chien, H.V., & Huan, N.H. (2007). Yellowing Syndrome of Rice: Etiology, Current Status, and Future Challenges. *Omontrice*, 15, 94–101.

Hashim, H. & Ang, O.C. (1984). Transmission of *Ragged stunt virus* Disease of Rice in Malaysia. *MARDI Research Bulletin*, 12(1), 95–101.

Helina, S., Sulandari, S., Hartono, S. & Trisyono, Y.A. (2018). Detection and Transmission of *Rice stunt virus* on Ciherang and Situ Bagendit Varieties. *Jurnal Hama Penyakit Tumbuhan Tropika*, 18(2), 179–186. https://doi.org/10.23960/j.hpt.218xx

Hibino, H. (1989). Insect-Borne Viruses in Rice. In K.F. Harris (Ed.), *Advances in Disease Vector Research* (vol. 6, pp. 209–241). New York, United States: Springer-Verlag.

Hibino, H. (1996). Biology and Epidemiology of Rice Viruses. *Annual Review of Phytopathology*, 34: 249–274. https://doi.org/10.1146/annurev.phyto.34.1.249

Hibino, H., Roechan, M., Sudarisman, S., & Tantera, D.M. (1977). A Virus Disease of Rice (*Kerdil Hampa*) Transmitted by Brown Planthopper, *Nilaparvata lugens* Stål, in Indonesia. Bogor, Indonesia : Contr. Centr. Res. Inst. Agric. 15 p.

Iswanto, E.H, Dadang, Winasa, I.W ., & Rahmini. (2019). Pengaruh Insektisida terhadap Kemampuan Adaptasi Wereng Batang Cokelat pada Varietas Padi. *Jurnal Penelitian Pertanian Tanaman Pangan*, 3(3), 125–133. https://doi.org/10.21082/jppptp.v3n3.2019.p125-133

Kusuma, A.F., Sulandari, S., Somowiyarjo, S., & Hartono, S. (2018). Molecular Diversity of Rice Ragged Stunt Oryzavirus in Java and Bali, Indonesia. *Proceeding of Pakistan Academy of Science. B. Life and Environmental Sciences*, 55(1): 57–64.

Kusumaningrum, S.F. (2018). *Penularan Virus Kerdil Padi oleh Wereng Batang Cokelat Resisten Imidacloprid*. (Unpublished bachelor thesis). Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Ling, K.C. (1977). Transmission of Rice Grassy Stunt by the Planthopper, In *The Rice Brown Planthopper* (pp. 73–83). Taipei, Taiwan: Food and Fertilizer Technology Center for Asian and Pacific Region.

Liu, S.H., Yang, B.J., Liu, S., Ding, Z.P., Liu, Z.W ., & Tang, J. (2012). Effects of Sublethal Dose of Imidacloprid and Pymetrozine on Relative Biological Fitness of Brown Planthopper, *Nilaparvata lugens*. *Chinese Journal of Rice Science*, 26, 361–364.

Liu, Z. & Han, Z. (2006). Fitness Costs of Laboratory Selected Imidacloprid Resistance in the Brown planthopper, *Nilaparvata lugens* Stål. *Pest Management Science*, 62(3), 279–282. https://doi.org/10.1002/ps.1169

Londingkene, J.A., Trisyono, Y.A., Witjaksono, & Martono, E. (2016). Relative Fitness and Feeding Capacity of Imidacloprid Resistant *Nilaparvata lugens*. *Jurnal Perlindungan Tanaman Indonesia*, 20(1), 43–49. https://doi.org/10.22146/jpti.17540

Matsumura, M., Takeuchi, H., Satoh, M., Morimura, S.S., Otuka, A., Watanabe, T., & Thanh, D.V . (2008). Species-specific Insecticide Resistance to Imidacloprid and Fipronil in the Rice Planthoppers *Nilaparvata lugens* and *Sogatella furcifera* in East and South-east Asia. *Pest Management Science*, 64(11), 1115–1121. https://doi.org/10.1002/ps.1641

Morinaka, T., Putta, M., Chettanachit, D., Parejarearn, A., & Disthaporn, S. (1983). *Trasmission of Rice Ragged Stunt Disease in Thailand*. *JAQR*, 17(2), 138–144.
Rivera, C.T., Ou, S.H., & Iida, T.T. (1966). Grassy Stunt Disease of Rice and its Transmission by the Planthopper Nilaparvata lugens Stål. *Plant Disease Reporter, 50*, 453–456.

Sparks, T.C. & Nauen, R. (2015). IRAC: Mode of Action Classification and Insecticide Resistance Management. *Pesticide Biochemistry and Physiology, 121*(2015), 122–128. https://doi.org/10.1016/j.pestbp.2014.11.014

Suprihanto, Somowiyarjo, S., Hartono, S., & Trisyono, Y.A. (2016). Preferensi Wereng Batang Cokelat terhadap Varietas Padi dan Ketahanan Varietas Padi terhadap Virus Kerdil Hampa. *Jurnal Penelitian Pertanian Tanaman Pangan, 35*(1), 1–8. https://doi.org/10.21082/jpptp.v35n1.2016.p1-8

Surahmat, E.C., Dadang, & Prijono, D. (2016). Kerentanan Wereng Batang Cokelat (Nilaparvata lugens) dari Enam Lokasi di Pulau Jawa terhadap Tiga Jenis Insektisida. *Jurnal Hama dan Penyakit Tumbuhan Tropika, 16*(1), 71-81. https://doi.org/10.23960/j.jptt.11671-81

Untung, K. & Trisyono, Y.A. (2010). Wereng Batang Cokelat Mengancam Swasembadha Beras. Retrieved from https://faperta.ugm.ac.id/download/publikasi_dosen/wereng_coklat_mengancam_swasembada_beras.pdf

Wang, Q., Li, J., Dang, C., Chang, X., Fang, Q., Stanley, D., & Ye, G. (2018). Rice Dwarf Virus Infection Alters Green Rice Leafhopper Host Preference and Feeding Behavior. *PLoS ONE, 13*(9), e0203364. https://doi.org/10.1371/journal.pone.0203364

Whitfield, A.E., Falk, B.W., & Rotenberg, D. (2015). Insect Vector-mediated Transmission of Plant Viruses. *Virolology, 479–480*, 278–289. https://doi.org/10.1016/j.virol.2015.03.026

Zadoks, C.J. & Schein, R.D. (1979). *Epidemiology and Plant Disease Management*. New York, United States: Oxford University Press.

Zhang, X., Liao, X., Mao, K., Zhang, K., Wan, H., & Li, J. (2016). Insecticide Resistance Monitoring and Correlation Analysis of Insecticides in Field Populations of the Brown Planthopper Nilaparvata lugens (Stål) in China 2012–2014. *Pesticide Biochemistry and Physiology, 132*, 13–20. https://doi.org/10.1016/j.pestbp.2015.10.003