



Research Article

Application of Vermicompost with Different Feeding Material for Inducing Rice Plant Resistance against Brown Planthopper (*Nilaparvata lugens* Stål.) Attack

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ABSTRACT

Brown planthopper (BPH) is a major pest in rice plants and has become a global pest. This pest causes hopperburn in rice plants. This research aimed to know the effect of vermicompost from different feeding materials on rice plant damage by brown planthopper attack. This research was carried out between November 2019–March 2020 at the Sistandu integrated farming system, Serang City, Banten. The experiment method used in this research was a factorial Randomized Block Design (RBD) and consisted of two factors with three replications. The first factor was vermicompost (P) with 5 levels, while the second factor was rice varieties (V) with two groups resulting in ten treatments. Data were analyzed with ANOVA, then followed by a 5% DMRT. The results showed that the application of vermicompost with different feeding materials had non-significant effects on growth of rice plants in the vegetative phase and fecundity of the BPH. However, it significantly affected the intensity of rice plant damage in the generative phase, the offspring population of BPH, and the BPH feeding rate. While the use of two varieties of rice did not have distinct effects on all parameters. There was no interaction effect between the two factors tested, both vermicompost feeding material treatment and rice plant variety, to all the parameters that have been studied.

Keywords: brown planthopper; rice plant variety; vermicompost

INTRODUCTION

Brown planthopper (*Nilaparvata lugens* Stål.) has been known to attack rice plants since 1931 on rice fields in the Dramaga Bogor area (Baehaki & Mejaya, 2014). Brown planthopper is widely distributed in the Palaearctic region (China, Japan, and Korea), Southeast Asia, and Australia (Fiji, Caledonia, Solomon Islands, and New Guinea). Data shows that BPH has now become a global pest that is difficult to control (Catindig *et al.*, 2009). One of the reasons for BPH population explosion was due to the development of insecticide resistance. Resistance can be defined as a change in inherited sensitivity of a pest population, which is reflected in the repeated failure of insecticides applications

to control pests at recommended dosages (Müller, 2000). In Indonesia, BPH attack outbreak had occurred in 1977–1976. It reached 242,427 ha damage (Dyck & Thomas, 1979). In 2010 and 2011 there were also quite high attacks that reached 223,656 ha (Thorburn, 2015), whereas in 2018, there was 95,431 ha rice infested by BPH (Direktorat Perlindungan Tanaman Pangan, 2018). BPH attacks always occur each year with fluctuating area of damage. Therefore, to maintain rice production in Indonesia, it is necessary to control BPH. Rice plant resistance to BPH can be stimulated by applying vermicompost, that are rich of nutrient (Adhikary, 2012) and bioactive compound such as humic acid (Martinez-Balmori *et al.*, 2014).

Vermicompost is a high-quality organic fertilizer that is produced from degradation of organic matter by earthworms. Earthworms produce vermicompost by softening the residue with saliva, neutralizing using calcium excreted from the inner wall of the esophagus, extracting particles, and breaking down using enzymes (Pereira *et al.*, 2014). In addition to high N content, vermicompost is high in potassium. Potassium can increase plant resistances to drought, pests, and diseases. Jafary-Jahed *et al.* (2020) explained that vermicompost improved the development of root systems and subsequently enhanced canola, white cabbage, and red cabbage resistance against *P. xylostella*.

Vermicompost is known to have many benefits, including containing various kinds of metabolites produced by earthworms. One of them is polyphenols (Nurhidayati *et al.*, 2018). Polyphenols are secondary metabolites required by plants to form resistances against brown plant hopper attacks. Vermicompost, according to Simsek-Ersahin (2011), is also rich in chitinase enzymes. This enzyme is beneficial for inducing plant resistances against pests and diseases because it can break down chitin substances in insect bodies and pathogenic cell walls. Chakraborty *et al.* (2015) showed that the effect of vermicompost in combination with biological fertilizers followed by a reduction in the dosage of inorganic fertilizers had a significant impact on the incidence of pests and diseases of mulberry plants such as whiteflies and thrips. Vermicompost can also suppress arthropod pests for instance cabbage whiteworms, tomato hornworms, and cucumber beetles, as well as piercing-sucking arthropods: such as scale insects, mealybugs, aphids, and spider mites (Arancon *et al.*, 2005). Application of vermicompost to the soil makes plants less attractive to pests and can suppress pest reproduction.

Vermicompost combined with banana weevil, eggshells, rice straw, and banana peel is expected to increase its metabolite content so that it further increases plant resistances and reduce the levels of pest attack. Based on the results of phytochemical screening, it was found that Kepok banana peels contained flavonoids, alkaloids, tannins or polyphenols, saponins, and triterpenoids (Zulkifli *et al.*, 2020). Tannins, alkaloids and saponin have poisonous compounds that can cause dizziness and may act as

food repellent (Lumowa & Bardin, 2018). These compounds are expected to be absorbed into plant roots, thus can induce rice plant immunity to *N. lugens*. Rice straw is agricultural waste that contains high amount of phenolic compounds (Elzaawely *et al.*, 2017) and silicate, and cation exchange capacity (Yang *et al.*, 2010). Meanwhile, eggshells, as kitchen and industrial food waste, is a rich source of mineral salts, mainly calcium carbonate, which corresponds to about 94% of the shell (Murakami *et al.*, 2007).

In addition, the selection of rice varieties will also affect BPH attack. It is expected that in this study, vermicompost treatment will interact positively with high-yielding planthopper-resistant varieties. At present, there are many types of new superior rice varieties, in particular Inpari 33 and Inpari 42. Both of these varieties have advantages in addition to high yields, also resistance to culm-fall and resistance to some type of BPH (*Balai Besar Penelitian Tanaman Padi* [BB Padi], 2019). Alternate and rotational use between varieties is recommended for BPH resistance management.

Research on vermicompost and rice plants variety against BPH (*N. lugens*) attack is still severely limited. Studies on the effect of vermicompost on pest attacks that have so far been carried out include; vermicompost suppressed *Myzus persicae* on corn (Edwards *et al.*, 2010) and vermicompost reducing *A. gossypii* populations in cucumber cultures (Razmjou *et al.*, 2012). Ruan *et al.* (2021) demonstrated vermicompost effects on increasing fragrancéd-rice production. Therefore, it is necessary to determine the effect of vermicompost application with different feeding material to induce rice plant resistance against brown planthopper (*N. lugens*).

MATERIALS AND METHODS

Site and Material

This research was conducted at the Gauze House Integrated Agricultural System (Sistandu) Banten. The study was conducted from October 2019 to March 2020. The materials used in this study were *Nilaparvata lugens*, Inpari 33 (modern inbred high-yielding lowland rice variety which is resistant to BPH biotype 1, 2, and 3, having moderately strong culm, having a yield of 6.6 ton/ha,

released by BB Padi in 2013), Inpari 42 (modern inbred high-yielding lowland rice variety which is moderately resistant to BPH biotype 1, moderately susceptible to BPH biotype 2 dan 3, having strong culm, having a yield of 7.11 ton/ha, released by BB Padi in 2016).

Research Methods

The experimental design used in this study was a factorial (5x2) Randomized Block Design. The first factor level was application of vermicompost from four different feeding materials that were banana weevil, banana peel, eggshell and rice straw and one treatment as control (without vermicompost, NPK fertilizer only). The second factor was rice plant variety that used Inpari 33 and Inpari 42. There were ten treatment combinations with three replications. The data was statistically analyzed using ANOVA (Analysis of Variance). Significance differences between treatment variations were tested by 5% Duncan Multiple Range Test (DMRT).

Vermicompost Production

Vermicompost was made for two months at the Jakarta Agricultural Technology Research Center (BPTP Jakarta). A plastic stacking cupboard was used as a vermicomposting container where each drawer was given holes for aeration. The dimension of the drawers were 50×30×25 cm. The basic media used was cow manure. Each treatment received 1 kg of vermicompost starter (*Lumbricus rubellus* worms). Additional 1.5 kg of cow manure was added as basic media. Then it was combined with feeding materials including banana weevil, banana peel, eggshells, and rice straw, each 1.5 kg. Before being applied as feeding material, they were finely chopped. Fresh vermicompost was harvested after 2 months.

Exploration and Propagation of the BPH

The BPH used in this study was collected using an aspirator from infested rice field owned by farmers in Sorodot Village and Kadupayung Village, Menes District, Pandeglang Regency, Banten Province. Collected BPH were brought and reared to obtain large populations. The hood was made of plastic, a 100 cm×60 cm gauze with a height of 120 cm and was maintained by continuously feeding the with 30-days-old Ciherang rice plants

taken from the field where the BPH originates. During maintenance, BPH individuals were kept away from predators (ants and spiders) (Darmadi & Alawiyah, 2018).

Vermicompost Applications

The medium was prepared a week before planting. The soil used for planting was taken from a plantation area in Rangkasbitung Region, Banten. The soil was taken and loosened using a hoe and shovel. It was then mixed with vermicompost using a ratio of 1:10 kg. The soil as planting media was shifted from boulders. Furthermore, soil was placed in a plastic pot (30 cm in diameter × 25 cm height) for each treatment. Pots were filled with 4 kg of soil and 0.4 kg of vermicompost according to the treatment. Basic fertilizers were given in small amounts, such as nitrogen (Urea) 0.30 g pot⁻¹, phosphorus (SP 36) as much as 0.40g pot⁻¹, and potassium (KCl) as much as 0.40g pot⁻¹. Basic fertilizers were applied a week before planting, while vermicompost was applied before planting by evenly mixing into planting medium according to the dosage (Herlina *et al.*, 2016). Afterward, pots were filled with water as high as 2 cm from the soil surfaces to maintain soil moisture and promote rice plant growth.

Rice Planting

Rice planting was done after rice seeds were two weeks old. Rice seedlings were selected and pulled from the nursery tub, then transferred or planted into plastic pots filled with muddy soil mixed with vermicompost and given complete fertilizer. Each pot contained three rice tillers which were made into a clump. After 35 days, plants were be used for bioassays (Darmadi & Alawiyah, 2018). Rice plants that were removed from the nursery and planted in plastic pots, they were immediately covered to avoid outside disturbances. Lids were made using four bamboo stakes around a plastic pot and then covered with gauze.

Infestation of BPH on Rice Plants

Infestation of BPH on rice was carried out when the rice plants were 35 days after planting (DAP). Each pot planted with rice and covered with gauze were infested with five 3rd nymphal stage

BPH using an aspirator. The damage that occurred on rice plants was observed 7–10 days after infection because at this time 90% of the varieties are prone to severe damage or death. Individual BPH were then removed to prevent further damage on other plants (International Rice Research Institute [IRRI], 2002).

Rice Planting for Oviposition Bioassay

BPH oviposition bioassay used rice plants were grown in plastic pots and replicated 3 times. Every pot was covered with a gauze. Five BPH at imago stage were infested to the rice plants at 14 days after planting. BPH eggs were counted at 30 DAP by dissecting in the laboratory.

Observation Variables

Plant damage score of BPH attack

Observation of rice plant damage was carried out twice during the vegetative stage, 7 days after BPH infested (42 DAP), by counting the number of damaged tiller. The second one was done when rice plants were in the generative stage, 65 DAP. Planthoppers cause plants to wilt, a symptom called hopperburn (Catindig *et al.*, 2009). The level of BPH attack was classified based on plants damage symptom (Table 1).

The data obtained was then used to calculate the level of damage on plants (IRRI, 2002). To count the BPH attack intensity, the used formula was as follow:

$$I = \sum \frac{(n \times v)}{(N \times V)} \times 100\%$$

I = intensity of damage, n = number of plants observed indicating a damage score, v = a designated score, N = number of plants observed, Z = highest damage value followed Minarni *et al.* (2018).

BPH Offspring

In each plant sample unit, the number of nymph contained in the stem segment was calculated manually. It was carried out after the BPH produced first offspring on 65 DAP plants. The selected tiller leaf samples were peeled off by opening the dry leaves on each segment and leaving only five young leaves at the top. Pest population observations were carried out once by counting the number of nymph present in each segment of the culm using a hand counter. According to Paparang *et al.* (2016), the following formula was used to count the average nymph population:

$$P = \frac{n}{N}$$

P = pest population, n = number of nymphs found in plants/clumps, N = number of clumps observed.

BPH Fecundity

BPH eggs are usually inserted into the bottom of rice leaves. All eggs laid by female BPH were taken out in the laboratory and counted under a microscope. Number of live and dead eggs were observed. Live leafhoppers' eggs will be oval and perfectly filled. In contrast, dead leafhoppers' eggs will be wrinkled and empty or not filled following Rashid *et al.* (2016). Fecundity (A) was calculated using the formula:

$$A = \frac{\text{number of hatched eggs}}{\text{number of produced eggs}} \times 100\%$$

Table 1. Standard evaluation system for brown planthopper (BPH) resistance

Damage Symptom	Damage Score	Resistance Level
No damage	0	Immune
Very slight damage	1	Highly Resistant
First and 2nd leaves of most plants partially yellowing	3	Resistant
Pronounced yellowing and stunting or about 10 to 25% of the plants wilting or dead and remaining plants severely stunted or dying	5	Moderate resistant
More than half of the plants wilting	7	Susceptible
All plants dead	9	Highly Susceptible

BPH Feeding rate

The honeydew excretion test was carried out to determine the reaction of BPH different feeding preference on seedling varieties of BPH, based on the number of honeydew produce. Honey dew was collected in feeding chambers consisted of a transparent plastic cup placed over a filter paper (Whatman No. 40 9 cm in diameter) resting on a plastic petri dish. Five 2-days-old adult females previously starved for 5 h were placed into the chamber through a hole at the top of the cup, then a cotton wad was plug in. BPH were allowed to feed for 48 hours. Then filter papers were collected and treated with 0.001% ninhydrin in acetone solution. After oven-dried for 5 min at 100°C, honeydew appeared as violet or purple stains due to their amino acid content. The area of visible spots were then counted using scores between 0 and 5. The implementation of the honeydew secretion test followed methods from Paguia *et al.* (1980).

RESULTS AND DISCUSSION

Rice Plants Damage by Brown Planthopper

In this study, the analysis showed no interaction among vermicompost application and rice plant varieties (Table 2), however, there was effects by vermicompost as single factor. Vermicompost application from various worm feeding material, resulted in significant effects on rice plant damage

level in generative phase, BPH population development aspect as well as the honeydew testing. Likewise with the treatment of varieties, both Inpari 33 and Inpari 42 did not significantly affect all parameters tested.

Provision of vermicompost with different worm feeding material did not affect the intensity of damage on rice plants by BPH during the vegetative phase (Table 3). However, due to BPH damage scoring criteria (IRRI, 2002), all treatments had the same score of 1 (very slight damage or one leaf showed yellowing), except for the control (P0) treatment, which did not receive addition of vermicompost, that had score of 3. This implies that from the criteria for plant damage scoring, the application of vermicompost with various kinds of worm feeding material was able to affect the response of plants to BPH attacks.

During the generative phase (Table 4), vermicompost application showed significantly effects on rice plants damage intensity due to BPH attack compared to control (P0). On the other hand, there was no significant difference between vermicompost made from four worm feeding material, namely banana weevil (P1), banana peel (P2), eggshell (P3) and rice straw (P4). Meanwhile, visual observation of the rice plants damage scoring showed that the highest score was category 7, which was found from the control (P0), banana weevil (P1) and eggshell (P3). Similarly, for the average

Table 2. ANOVA of vermicompost with different worm feeding material in two varieties of rice plants (*Oryza sativa*) effect on *Nilaparvata lugens* damage and life aspects

No. Observation Parameters	Treatment		Interaction	Diversity Coefficient (%)
	Vermicompost	Varieties		
Plant Damage Intensity				
1. Damage Intensity in vegetative phase	ns	ns	ns	15.96
2. Damage Intensity in Generative Phase	**	ns	ns	7.42
Components of the Development of Brown Stem Planthoppers				
1. Fecundity brown stem planthoppers	ns	ns	ns	8.33
2. 2nd Generation Population	**	ns	ns	22.95
3. Honeydew Test Scoring	*	ns	ns	26.63

Note: * and ** = significantly different at 5% and 1% of DMRT respectively, ns = not significant

Table 3. Average intensity of rice plant damage in vegetative phase (%) by brown planthopper (BPH)

Vermicompost	Varieties		Average	Plant damage score
	Inpari 33	Inpari 42		
P0	14.83	18.20	16.52 ^a	3
P1	13.10	14.43	13.77 ^a	1
P2	12.56	9.83	11.20 ^a	1
P3	15.30	13.50	14.40 ^a	1
P4	17.70	11.40	14.55 ^a	1
Average	14.70 ^a	13.47 ^a		
Score	1	1		

Note: P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw).

Score 1: very slight damaged. The numbers followed by the same letter in the same column or row showed no different according to the DMRT test at rate of 5%.

Table 4. Average intensity of rice plant damage vermicompost treatment in generative phase (%) by brown planthopper (BPH)

Vermicompost	Varieties		Average	Plant damage score
	Inpari 33	Inpari 42		
P0	57.70	56.73	57.22 ^a	7
P1	48.73	51.00	49.87 ^b	7
P2	48.27	47.57	47.92 ^b	3
P3	47.13	52.63	49.88 ^b	7
P4	46.50	50.93	48.72 ^b	5
Average	49.67 ^a	51.77 ^a		
Score	7	7		

Note: P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw).

The numbers followed by the same letter in the same column or row showed no different according to the DMRT test at rate of 5%.

damage per variety, both Inpari 33 and Inpari 42 varieties had a score of 7. Furthermore, vermicompost from rice straw (P4) was included in the category score 5, while vermicompost from banana peels (P2) had an average damage criteria with the lowest score. i.e. 3.

BPH Growth on Rice plant with Vermicompost Application

Average number of eggs laid by female BPH on two rice varieties applied with vermicompost are presented in Table 5. It can be seen that the average ability of female BPH to lay eggs in Inpari 33 and Inpari 42 varieties were not significantly different and similar to vermicompost feeding material treatment as well. In this study, the number of BPH offspring in the first generation was also calculated (Table 6).

The average number of BPH offspring was not significantly different in two rice varieties treatment. However, on the vermicompost factor, there was a significant effect between the type of feeding material to BPH offspring population. P0 was the treatment with the highest number, 72.67 individuals, while eggshell vermicompost (P3), was the lowest one, only reached 19.33 individu. The average score of BPH feeding ability was also observed (Table 7). Statistically, the provision of vermicompost with various worm feeding material had a significant effect on the quantity and quality of honeydew produced by BPH. The observation showed that BPH feeding on treatment P0 had the highest honeydew excretion score among other treatments, followed by P3 and P1, P4, and the lowest was at P2. This is also supported by Figure 1, which shows the alignment with the data.

Table 5. Average brown planthopper (BPH) fecundity (%) on two rice variety with vermicompost from different feeding material

Vermicompost	Varieties		Average
	Inpari 33	Inpari 42	
P0	90.72	89.51	90.12 ^a
P1	87.53	90.44	88.99 ^a
P2	83.08	79.60	81.34 ^a
P3	78.93	86.70	82.81 ^a
P4	79.29	83.17	81.23 ^a
Average	83.91 ^a	85.88 ^a	

Note: P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw).

The numbers followed by the same letter in the same column or row showed no significantly different according to the DMRT test at 5% rate. No significant interaction effects between both factors.

Table 6. Average number of brown planthopper (BPH) offspring on two rice variety with vermicompost from different feeding material

Vermicompost	Varieties		Average
	Inpari 33	Inpari 42	
P0	80.33	65.00	72.67 ^a
P1	30.67	21.00	25.83 ^{cd}
P2	33.33	31.33	32.33 ^c
P3	21.67	17.00	19.33 ^d
P4	47.00	36.00	41.50 ^b
Average	42.60 ^a	34.06 ^a	

Note: P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw).

The numbers followed by the same letter in the same column or row showed no different according to the DMRT test at 5% rate. No significant interaction effects between all factors.

Table 7. Average brown planthopper (BPH) honeydew test score on two rice plant with vermicompost from different feeding material

Vermicompost	Varieties		Average
	Inpari 33	Inpari 42	
P0	2.35	2.35	2.35 ^a
P1	1.77	1.81	1.80 ^{bc}
P2	1.29	1.27	1.28 ^d
P3	2.20	1.90	2.05 ^b
P4	1.64	1.56	1.60 ^c
Average	1.85 ^a	1.78 ^a	

Note: P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw).

The numbers followed by the same letter in the same column or row showed no different according to the DMRT test at 5% rate. No significant Interaction effect between all variation.

Discussion

There was an indirect effect of vermicompost application to rice plants in dealing with brown planthopper pests. Rice plants, both Inpari 33 and Inpari 42, were more resistant to BPH attack when media was vermicompost applied. Data from Table 3 showed that vermicompost with different feeding

material did not give significant effect to rice plant damage in vegetative phase. It is presumed related to characteristic of organic matter from each vermicompost which take time to be degraded and released in the soil, so that it finally can be absorbed by roots. On the other hand, the intensity of rice plants damage during the generative phase increased

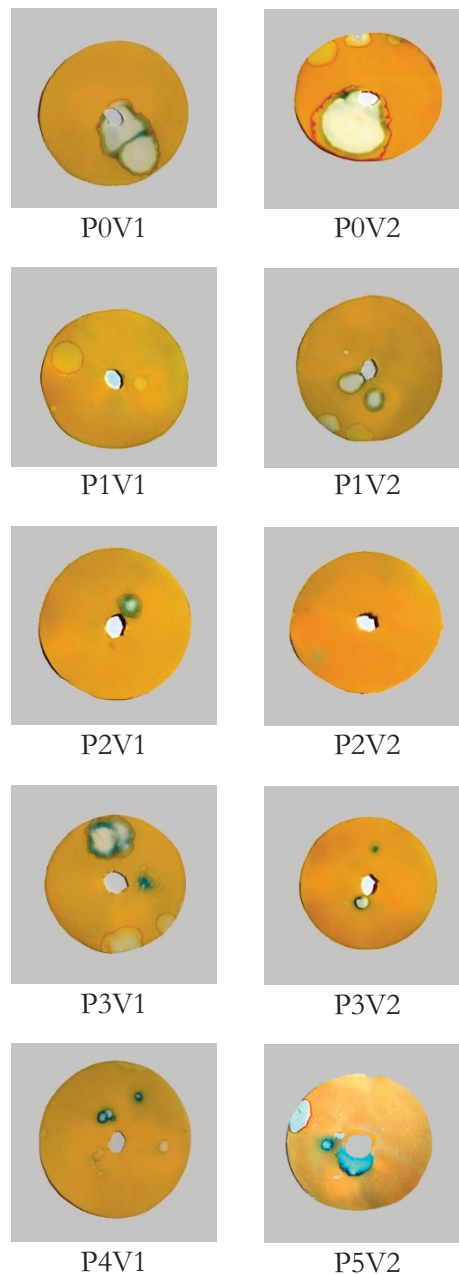


Figure 1. Honeydew excreted by brown planthopper (BPH) on two rice varieties with vermicompost from different feeding material; P0 (no vermicompost), P1 (banana weevil), P2 (banana peel), P3 (eggshell), P4 (rice straw); V1 (rice variety 1, Inpari 33), V2 (rice variety 2, Inpari 42)

compared to the vegetative phase, this is associated with the increasing population of BPH. Baehaki and Mejaya (2014) stated that BPH reproduces at an exponential growth rate which is a strategic character of pests and damage rice plants after reaching 2–3 generations, because nymph populations are enormous at these stages. However, applying vermicompost was able to reduce the level of damage when compared to controls. Thus, it can be said that the resistance of both rice varieties to

BPH has increased. BPH has a stylet mouth part, which is used for sucking phloem sap nutrient content, reducing chlorophyll, and interrupting photosynthesis rate (Watanabe & Kitagawa, 2000; Baehaki & Mejaya, 2014). The liquid component in plant tissue is certainly strongly influenced by the type of material, both organic and inorganic materials that are absorbed by plant roots. Furthermore, these materials will be processed in metabolic reactions, some of which are broken down into

other smaller molecules, transferred in different forms, or used to compile more complex organic matter (Karamanos, 2013). The existence of vermicompost significant effect on BPH attack indicates that there are vermicompost elements which when absorbed by plants will induce plant performance so that it is more resistant to BPH. Chau and Heong (2005) reported that manure and organic fertilizers were more effective than chemical fertilizers to induce rice plant growth and tolerance to BPH, stem borer and leaf folder. Main mechanism of defense in rice variety was recorded by low nitrogen and phosphate content and high potassium and secondary metabolite content in rice plant.

Vermicompost addition affected BPH population growth. In this study, this was measured by the fecundity of BPH, the population of its offspring, and the amount of honeydew produced. Despite the fact that female BPH fecundity was not affected by the treatment with vermicompost or the type of rice variety, the number of BPH offspring that observed in 45 DAP turned out to have a significant effect on the vermicompost treatment. Likewise in the BPH feeding rate as seen from the honeydew score. Vermicomposting is a mesophilic process that utilizes microorganisms and earthworms that are active at 10°C to 32°C (Adhikary, 2012). Yardim *et al.* (2006) reported that in the greenhouse, both the 20% and 40% vermicompost substitution rates decreased damage by cucumber beetles to cucumber foliage and hornworms to tomato foliage. This may be related to the presence of secondary metabolic compounds elicitor such as silicates and humic acid in plants grown with vermicomposts. This is in accordance with the opinion of Wulanjari *et al.* (2020), who concluded that the polyphenol content were stimulated by the mineral elements calcium, silica, iodine, and potassium can reduce the leaf rust disease suppression caused by *Hemileia vastatrix* incidence up to 78.13%. Noroozisharaf and Kaviani (2018) indicated that humic acid affected secondary metabolites (quantity and quality of chemical compositions) and nutrients uptake in *T. vulgaris*, such as monoterpene hydrocarbons and sesquiterpene hydrocarbons. It is known that the metabolite compounds related to defense against herbivorous insects are divided into 3 main groups, namely

phenolic compounds, terpenes, and N-containing compounds such as alkaloids (Taye & Borkataki, 2020). Unfortunately, what are the vermicompost compounds that can be directly absorbed by the roots, how these compounds are involved in the biosynthesis of secondary metabolites related to plant defenses against herbivores, especially BPH, is not known clearly at present. However, this aspect was not measured in this study.

The next possibility is due that vermicompost is an appropriate medium for the growth and development of beneficial microorganisms. They can stimulate bioactive matters related to the metabolism of plant defense elicitor substances against herbivorous insects. Worm castings are much higher in nutrients and microbial life (Jiang *et al.*, 2020). The microbial complex around the roots may produce and induce important growth regulators for rice plants, such as certain hormones and enzymes. Furthermore, these substances will be involved in the biosynthesis of important secondary metabolites, such as jasmonic acid and salicylic acid. The results of research by Senthil-Nathan *et al.* (2009) indicated that JA application induces systemic defenses in rice that has a direct negative impact on *N. lugens* survivorship. At high concentration (5mM) several abnormalities possibly related to defective moulting, were observed along with malformed eggs. Peng *et al.* (2004) relayed that spraying tomato plants with a solution containing either SA or methyl salicylic acid (Me-SA), will increase the H₂O₂ level. This substance involved in tomato plant defense responses to the herbivore. In future research, it is necessary to measure these substances both in vermicompost and in plant tissue.

Accordance with Table 6 and 7, the feeding material of *Lumbricus rubellus* worms in vermicomposting had indirect significant effect on the development of BPH. Vermicompost made with banana peels (P2) is the best treatment due to the plant damage score in generative phase that only reached score 3, it has the resistant level criteria (Table 4). In addition, P2 treatment also has the lowest BPH offspring number, thus it is in conforming with the honeydew produce scoring (Figure 1). Meanwhile, vermicompost made from eggshell had the least number of BPH offspring among others, but it had

a high score of honeydew i.e. 2.05. In spite of that, when compared to control plants without vermicompost (P0), P0 was the treatment with the highest population of BPH and honeydew score. It indicated that vermicompost addition enhanced rice plant resistance to sucking insect. This is presumably because banana peels are richer in their constituent materials, hence when decomposed by *L. rubellus* worms, they are degraded into higher quality organic substrates. Contradictory, eggshell and rice straw feeding material, although actually rich in protein and chitin (Hastuti *et al.*, 2021). Straw combined with nanocarbon showed the highest vermicompost quality. The application of straw promoted earthworm growth and cocoon production in vermicomposting (Cao, 2021). However, in this study *L. rubellus* worms seem to had different ability to consume and convert different material influencing the biological and chemical degradation process. Probably it owing to the difficulty to digest, or it takes a longer time for the vermicomposting process.

CONCLUSION

The use of vermicompost with different worm feeding material affected some of the experimental parameters. It can reduce the plant damage by BPH in generative phase. Rice plants that were given vermicompost experienced moderate attacks while rice plants without vermicompost as control treatment experienced severe attacks. The use of vermicompost from banana peel gave the best results in reducing the average BPH feeding rate, while vermicompost from eggshell gave significant influence of BPH lowest offspring number. All treatments did not affect BPH fecundity. The use of two rice varieties, Inpari 33 and Inpari 42 did not have significantly different results for all experimental parameters. There was no interaction between the use of vermicompost with different types of waste with two rice varieties on the intensity of the BPH attack.

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