Silica Content On Local Rice Varieties Against Brown Planthopper Nilaparvata lugens Stall. (HEMIPTERA : DELPHACIDAE)*

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ABSTRACT

Rice (Oryza sativa L.) is the most critical crop in Indonesia. Problems encountered to increase rice production are pests attack mainly a brown planthopper. Silica as a biochemical for rice resistance to brown planthopper attack. This study examines the silica content of several local rice varieties and the correlation between the silica content and the brown planthopper attack. This research was conducted in Karanglo village, Klaten Regency Polanharjo and the Research Institute of Agricultural Environment in Jakenan Pati. Materials used local aromatic rice (Rojolele, Mentikwangi, Mentiksusu, Pandanwangi) and non-aromatic (Rojopusur, Padi Merah, Srikiti, Saudah, Slegreng) and IR 64 as comparison variety. The results showed that the generative phase silica content was higher than the vegetative phase. The highest silica content on the vegetative phase was found in IR 64 variety at 19.02% and the lowest was found in Srikiti varieties at 11.02%. The highest generative phase silica content was found in Srikiti varieties of 28.09% and the lowest was found in Rojolele variety of 15.47%. The increase in silica content significantly reduce the brown planthopper population.

Keywords : Brown planthopper, Local rice, Silica content

1 INTRODUCTION

Brown planthopper (BPH) is the most damaging pest of rice and causes severe yield losses and causes viral disease transmission [1]. In 2010 the brown planthopper became a global pest because it attacked rice plantations in Indonesia, China, Vietnam, Thailand, India, Pakistan, Malaysia, the Philippines, Japan, and Korea [2]. The loss of rice yields due to brown planthopper attacks reached 2 t/ha with an attack area of 218,060 ha [3]. In Indonesia, the brown planthopper attack causes a 100% decrease in rice yields [4]. The brown planthopper is very adaptive because it can form new biotypes [5]. This causes the process of introducing resistant varieties of brown planthopper to continue [6]. Rice resistance to BPH had played a significant role in integrated control strategies for this pest throughout East and Southeast Asia [7].

Local rice varieties are considered a source of genetic variation with drought tolerance and varying degrees of resistance to insect pests and diseases [8]. Besides, local rice varieties have different chemical composition, color, nutrition and taste characteristics [9]. Indonesia has many local rice varieties that are resistant to inundation and salinity because they have the Sub1A gene [10]. According to Horgan et al., (2015) that the local rice varieties have a higher resistance to brown planthopper than other varieties. Local rice varieties with the Bph6 gene are effective against Southeast Asian populations [12]. The population of BPH at VUTW (IR 64) was not significantly different for local varieties (Rojolele, Rojopusur, and Situbagendit), with the highest nymph population was Membramo and the lowest was Situbagendit [13].

Naturally, all plants have resistance to pest attacks. Plant selection by herbivores is influenced by plant biophysics and biochemistry with two mechanisms against insect pests, namely physical or mechanical barriers and biochemical or molecular mechanisms [14]. The content of silica in plants is one of the biochemical mechanisms as a direct defense in regulating plant defense lines against insects [15]. Silica is an essential element in plant nutrition which is translocated through the xylem to the shoots and then condenses into polymerized silica gel [16]. Silica increases plant resistance and reduces crop damage caused by pathogens, insect pests and non-insect pests through the mediation and regulation of both resistance mechanisms that are constitutive (i.e., regardless of the presence of insects) and induced (i.e., in response to insect attack) [17]. Silica makes plant tissue difficult for insects to chew, penetrate and digest efficiently. Besides, the beneficial role of silica

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in plant physiology, regulation of defense-related enzymes, plant hormone signaling and alteration of volatile plant mixtures explain the relationship of silica with biochemical/molecular defense mechanisms [18].

Rice plants with sufficient silica will have silica-coated tissue to be more resistant to attacks by various diseases both by fungi and bacteria, such as blast and bacterial leaf blight. The application of silica significantly decreased the plant hopper population and the higher the Silica content increased the resistance of rice plants to brown planthoppers [19]. With sufficient silica, the plant stems become more robust and more stocky so that they are more resistant to attack by stem borer, brown planthopper, and plants do not fall easily [20]. Plant tissue hardness is the first protection for plants against pest attack [21]. The strength of the plant stems as protection from pests is influenced by the silica content [22]. A study is needed to analyze the silica content of several local Indonesian rice varieties and the relationship between the silica content and the BPH population. Studies on silica content, which is one component of plant defense against pests in local rice varieties, have never been carried out. This study aims to identify silica levels in several local rice varieties and see BPH' preferences for local rice varieties.

2 MATERIAL AND METHODS

2.1 Study Sites

The research was conducted in a BPH endemic area in Klaten Regency, Central Java, which is located at 1100 26 '14 "- 1100 47' 51" East Longitude and .70 32 '19 "- 70 48' 33" South Latitude, with an altitude of 100 - 500 meters above the surface sea, rainfall 1600-2700 mm/year, and temperature 25-340C. The materials were used include aromatic local rice consisting of Rojolele, Pandanwangi, Mentikwangi, and Mentiksusu; non-aromatic varieties namely Rojopusur, Saudah, Padi Merah, Slegreng, and Srikiti. As a comparison, the IR 64 variety known to be resistant to BPH was used. Silica analysis was carried out at the Jakenan Pati Agricultural Environment Research Institute. Silica analysis using 25% HCl with a weighing device, oven and furnace.

Rice planting was carried out in rice fields through cultivation by the regulations of the Ministry of Agriculture. Each variety was planted in a block measuring 150m2 with a spacing of 22.5x22.5cm with two seeds/planting holes. During the research, no insecticide spraying was carried out. Weed control was done manually.

2.2 Silika content

Observation of stem silica levels was carried out at the vegetative stage of 30 days after transplanting (DAT) and 90 DAT. The method of analysis of silica content was compatible with [23] it was using 50 grams of dry straw with the sample soaked in hot water for 2 hours to extract water-soluble organic matter so that it does not become impurity. Silica extraction was carried out by the precipitation method, then the extraction results were analyzed quantitatively by gravimetry. The result of the observation was the SiO2 content of each local paddy variety [23].

2.3 Rice resistance to brown planthoppers

The variety's resistance to BPH was determined by counting the BPH population in field experiments. Planthopper population observations were carried out during the transitional growing season from rainy to dry. Observations were made from 2 Weeks After Transplanting (WAT) to 12 WAT by counting the number of BPH’s nymph and adult. Observations were carried out randomly on 30 plants per variety/subplot. The difference in the BPH population will be used as a parameter to compare resistance between varieties.

2.4 Data analysis

Data on silica levels and population were tested for normality and transformed if needed (Gomez and Gomesz 1984). Silica content data was displayed in the form of a histogram using Excel 2013. The mean silica content between varieties was compared using the T-test at 5% level with SPSS software. Data on the BPH population is displayed in graphical form using Excel 2013. Simple regression and correlation were carried out to estimate the relationship between silica levels and the BPH population using SPSS software.

3 RESULT AND DISCUSSION

The results showed that the silica content of aromatic and non-aromatic rice increased in the generative phase (Fig. 1). Silica levels increase with plant growth [19]. The silica content of aromatic and non-aromatic rice in the vegetative phase was not significantly different about 15%. Rice is an silica-collecting plant, with a silica-content reported to be as high as 10% of the total shoot dry weight [16]. However, the silica content of aromatic and non-aromatic rice in the generative phase were significantly different. The silica content of non-aromatic rice in the generative phase was higher than aromatic rice. This is due to reduced intracellular Si accumulation resulting in decreased Si availability in the leaf epidermal cell walls [24]. The results of this study are in line with [25] that non-aromatic rice has higher nutritional content including carbohydrates, Ca, Zn, Na, K, oleic acid, linoleic acid, palmitic acid and stearic acid compared to aromatic rice.

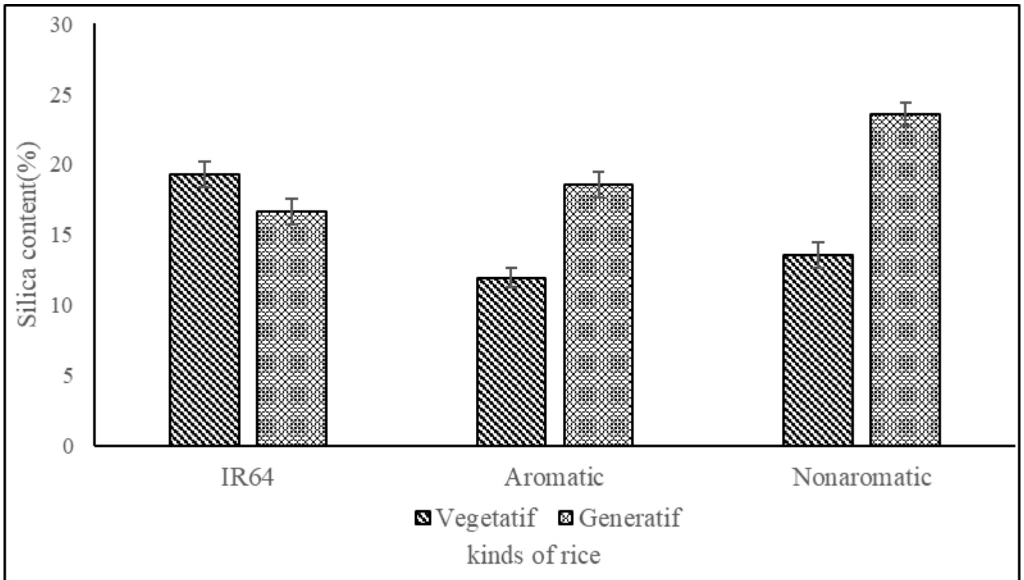
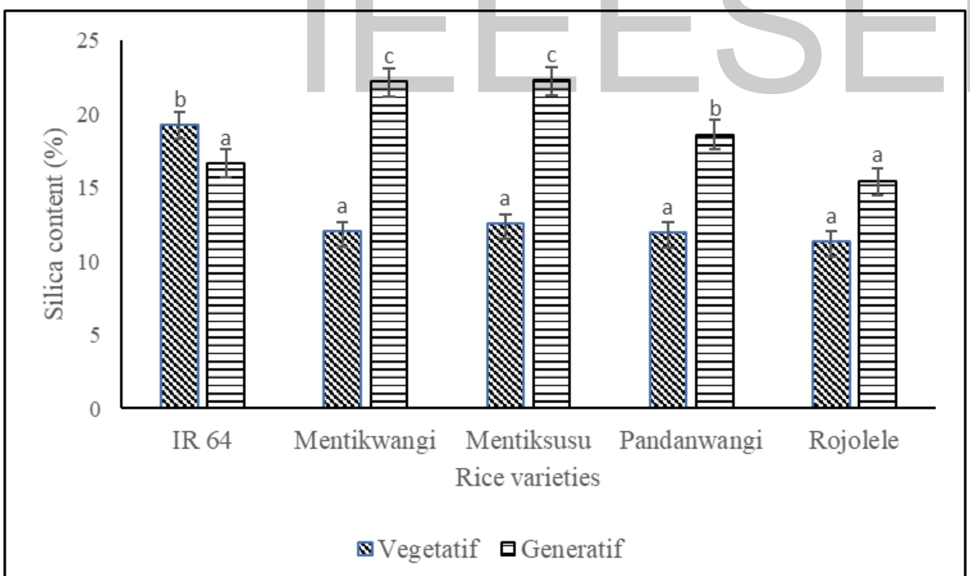


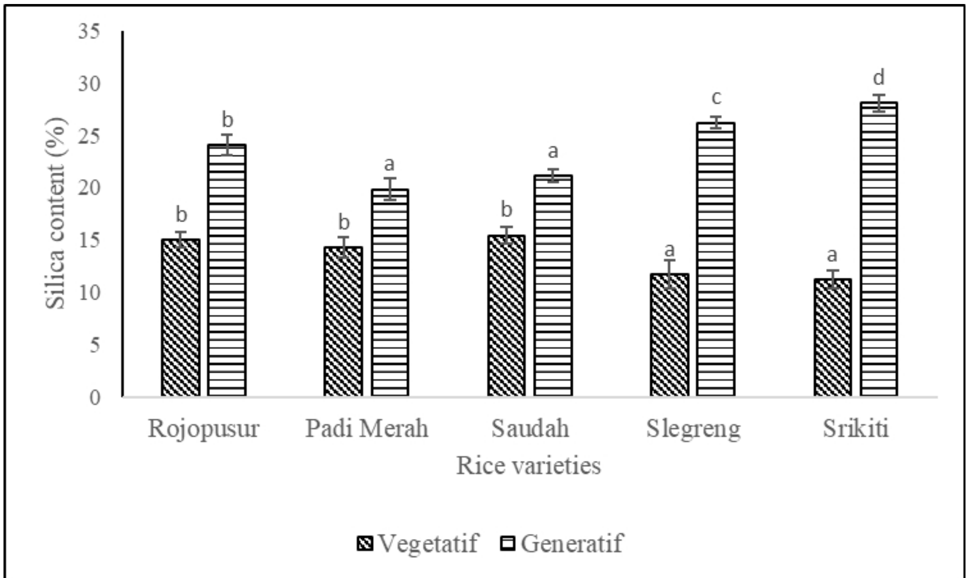
Fig 1. Histogram of silica content on rice aromatic and non-aromatic

Mentiksusu, the aromatic rice had the highest silica content in the vegative phase, namely 12.56% (Figure 2). Based on [26] that the categories of silica accumulation in plants are high (10–15%), medium (1-3%) and low (<1% Si, dm) accumulators. The silica content of aromatic rice during the vegetative phase was lower than IR 64. In general, there was an increase in silica levels in the generative phase, the highest increase was shown by the Mentikwangi and Mentiksusu varieties, respectively 22.17% and 22.28%, which were significantly different from IR 64 (16.65%). IR 64 decreased silica levels during the generative phase (Figure 2). During the generative phase, silica content in non-aromatic rice increased more than aromatic rice. This is because in the generative phase, the nitrogen uptake of aromatic rice is higher [27]. The higher the plant nitrogen, the reduced silica content [28].



Different notations on the same shading show significantly different levels of 5% according to the T test
Figure 2. Histogram of silica content on aromatic rice varieties

The silica content of non-aromatic rice varieties Srikiti and Slegreng were relatively low during the vegetative phase, namely 11.71% and 11.27%. The silica content of Srikiti and Slegreng were significantly different from Padi Merah, Saudah, and Rojopusur. Slegreng and Srikiti are local Wonogiri rice. Meanwhile, Rojopusur, Saudah, and Redrice are Klaten's local rice fields. The increase in silica content occurred during the generative phase for all non-aromatic rice. Slegreng and Srikiti showed the highest silica content, respectively 26.21% and 28.09%, significantly different from the other three local rice fields. Rice with high silica content will make it difficult for pests to attack due to the plant tissue's hardness. The hardness of plant tissue and thickening of epidermal tissue and palisade cells are conditions that make plants resistant to pest attack [29]. The hardening of the stems of rice plants causes pests with a sucker stick mouth to attack because the hard stem causes the mouth to wear out [30]. The silica membrane or double silica layer will make the plant resistant to pests [28].



Different notations on the same shading show significantly different levels of 5% according to the T test

Figure 3. Histogram silica contens on non-aromatic rice varieties

3.1 Brown planthopper population

The planthopper starts coming to the plant when the plants were 2 WAT, the population continued to increase until the plants were 4 WAT. The highest BPH population in aromatic rice was at the age of 3 WAT in Mentiksusu with an average of 3.80 heads per hill. This was because the silica content in the Mentiksusu variety was also low (Fig. 2). Silica has a negative correlation with survival and bodyweight of brown planthopper [4]. Si-mediated resistance can be realized through primary chemical defense reactions in plants that are intensified by physiological and mechanical barriers resulting from silica deposition in plant tissues [31] or decreased digestive efficiency in herbivores [32]. The brown planthopper population in Mentikwangi was lower than that of other aromatic groups (Fig 4). This is because the Mentikwangi variety has higher antixenosis resistance so that brown planthoppers cannot reproduce in these varieties [33].

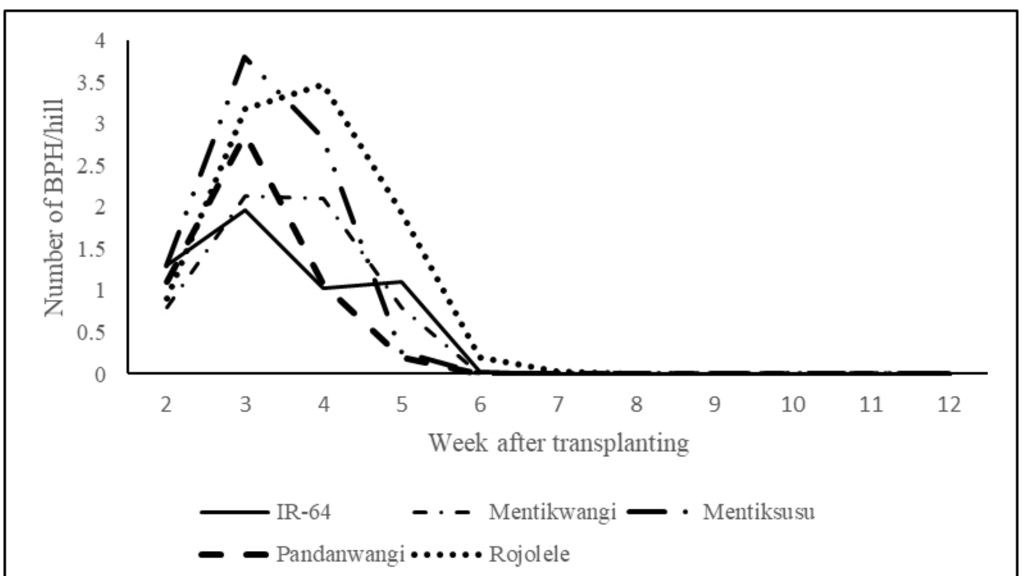


Figure 4. Population of BPH on local aromatic rice varieties

The highest BPH population in local non-aromatic varieties was found in Srikiti as much as 3.17 individuals / family, while the lowest was on IR 64 (Fig. 4). This was due to the low vegetative phase of the silica content of the Srikiti variety (Fig. 3). Silica as an essential element

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for plant growth as a pseudo-essential [30]. In addition, silica can affect crop defense indirectly through the release of plant volatiles [34], This compound can act either as an attractant or direct insect repellent so that the brown planthopper that sucks rice with high silica content will decrease [35]. Plant volatile emissions can be constitutive or can be induced in response to stress and as a defense reaction induced by herbivores [11]. In wheat plants with high silica the percentage of insects that eat phloem sap is reduced [33]. The increase in BPH populations reached its peak in all local varieties at 3 WAT except for IR-64 which was resistant variety to this pest.

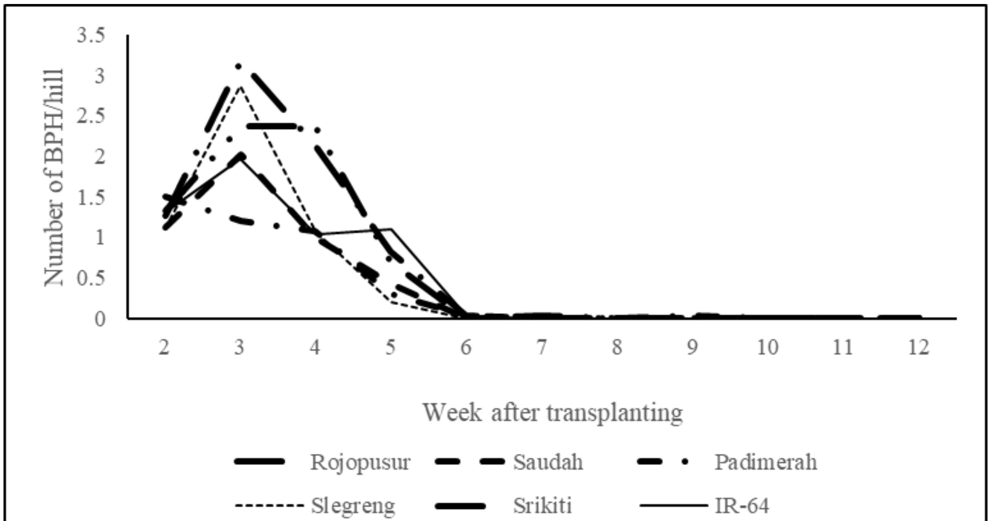

Figure 5. Population of BPH local non-aromatic rice varieties

Based on Fig. 5, the lowest BPH population was in the Padi Merah variety, while the highest was in the Srikiti variety. The difference in BPH population was due to differences in biophysical characters and different resistance between varieties. The morphological character of plants is one of the keys to plant resistance. According to [14] that variations in leaf size, shape, color, and the presence/absence of glandular secretions may play a role in determining the host's insect acceptance. Besides, the resistance of rice to BPH attack is also influenced by plant phloem tissue's character. The resistance of plant phloem tissue is influenced by the chemical elements contained therein, such as silicates, oxalates, phenolic acids, sterols, and apigenin glycosides [36].

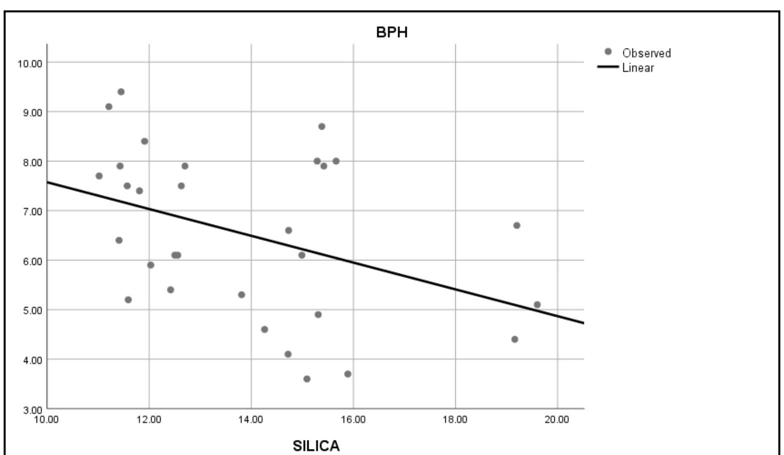

Fig 6. The relationship between the BPH population and the silica content of rice

Simple regression analysis showed that silica content significantly decreased of BPH population at 5% level ($y = -0.271x + 10.279$ with a value of $R2 = 0.163$, $F = 5.437$, $P < 0.05$) (Fig. 6). Silica can protect plants from stem borer, green leafhoppers, brown leafhoppers, white-back leafhoppers, and mites [15]. Based on the results of field studies conducted [37]. [14] shows that there is a positive correlation between silica content and plant resistance to brown planthopper attack. The silica content of the plant influences the level of attack by stem borer [38]. The content of silica in plants can strengthen plant resistance directly and indirectly to insect pests by depositing $SiO2$ as a biogenic opal (phytoliths), especially in leaf, stem and root epidermal cells [17]. Silica is deposited as a 2.5 µm thick layer just below the cuticle layer (0.1 µm thick), forming a silicon-cuticle double layer on the blades of paddy leaves [15]. The abrasive nature of leaves and other plant tissues associated with protection, storage, support, and reinforcement leads to irreversible increased wear of the mouthparts while the insects are eating, thus preventing the chewing insects [39]

4 CONCLUTION

The silica content increases with plant growth. The highest silica content in the vegetative phase was found in the IR 64 variety at 19.02% and the lowest was found in the Srikiti variety at 11.02%. The generative phase's highest silica content was found in the Srikiti variety at 28.09 %% and the lowest was found in the Rojolele variety at 11.31%. The increase in silica content can reduce the brown planthopper population.

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REFERENCES

[1] C. T. Zimmer *et al.*, "Neofunctionalization of Duplicated P450 Genes Drives the Evolution of Insecticide Resistance in the Report Neofunctionalization of Duplicated P450 Genes Drives the Evolution of Insecticide Resistance in the Brown Planthopper," *Curr. Biol.*, vol. 28, no. 2, pp. 268-274.e5, 2018, doi: 10.1016/j.cub.2017.11.060.

[2] S. E. Baehaki and K. L. Heong, "Impact of Nutrient Management on Pest and Yield of Different Rice Varieties," *Res. J. Agric. Environ. Manag.*, vol. 5, no. 7, pp. 243–252, 2016.

[3] U. Susanto, Nafisah, R. WR, S. Baehaki, S. Abdulrahman, and J. Ali, "Genetic Variability and Heritability of Green Super Rice Resistance to Rice Ragged Stunt Virus and Rice Grassy Stunt Virus," *Penelit. Pertan. Tanam. Pangan*, vol. 3, no. 3, pp. 111–116, 2019.

[4] Y. Wu *et al.*, "Identification and analysis of brown planthopper-responsive microRNAs in resistant and susceptible rice plants," *Sci. Rep.*, no. January, pp. 1–15, 2017, doi: 10.1038/s41598-017-09143-y.

[5] B. S. Haliru, M. Y. Rafii, N. Mazlan, S. I. Ramlee, and Y. R. Bashir, "Recent Strategies for Detection and Improvement of Brown Planthopper Resistance Genes in Rice : A Review," *Plants*, vol. 9, no. 1202, pp. 1–19, 2020.

[6] S. H. Akula, M. Dass, S. Surapaneni, and P. Balaravi, "Mapping of quantitative trait loci associated with resistance to brown planthopper in background of Swarna from a traditional variety PTB33," *Euphytica*, vol. 4, no. 216, 2020, doi: 10.1007/s10681-020-02652-4.

[7] Y. Tamura *et al.*, "Map-based Cloning and Characterization of a Brown Planthopper Resistance Gene BPH26 from Oryza sativa L. ssp. indica Cultivar ADR52," *Sci. Rep.*, vol. 4, no. 5872, pp. 1–8, 2014, doi: 10.1038/srep05872.

[8] P. Gangaraju, T. Shivashankar, and H. C. Lohithaswa, "Genetic Basis of Resistance to Brown Plant Hopper (Nilaparvata lugens Stal) in Genetic Basis of Resistance to Brown Plant Hopper (Nilaparvata lugens Stal) in Local Landraces of Rice," *Int. J. Curr. Micribilogy Appl. Sci.*, vol. 6, no. 8, 2018, doi: 10.20546/ijcmas.2017.608.405.

[9] A. Chairunnisak, B. Sugiyanta, and E. S. B, "Nitrogen Use Effi ciency of Local and National Aromatic Rice Varieties in Indonesia," *J. Trop. Crop Sci.*, vol. 5, no. 3, pp. 79–88, 2018.

[10] E. N. Khasna, I. K. Karisma, G. Ardana, and A. S. Zakiyah, "Sub1A gene screening for submergence stress in Indonesian local rice varieties," *AIP Conf. Proc. 2260,* vol. 060012, no. September, 2020.

[11] F. G. Horgan *et al.*, "Virulence of brown planthopper (Nilaparvata lugens) populations from South and South East Asia against resistant rice varieties," *Crop Prot.*, vol. 78, pp. 222–231, 2015, doi: 10.1016/j.cropro.2015.09.014.

[12] M. Yang *et al.*, "ScienceDirect Identification of a novel planthopper resistance gene from wild rice (Oryza ru fi pogon Griff .)," *Crop J.*, vol. 8, no. 6, pp. 1057–1070, 2020, doi: 10.1016/j.cj.2020.03.011.

[13] R. Wijayanti, Sholahuddin, Supriyadi, and S. H. Poromarto, "Population of brown planthopper in local rice varieties Population of Brown Planthopper in Local Rice Varieties," *AIP Conf. Proc.*, vol. 020035, no. September, 2018, doi: https://doi.org/10.1063/1.5054439.

[14] S. Hagenbucher, D. M. Olson, J. R. Ruberson, F. L. Wäckers, and J. Romeis, "Resistance Mechanisms Against Arthropod Herbivores in Cotton and Their Interactions with Natural Enemies," *CRC. Crit. Rev. Plant Sci.*, vol. 32, no. July, pp. 37–41, 2013, doi: 10.1080/07352689.2013.809293.

[15] F. Alhousari and M. Greger, "Silicon and Mechanisms of Plant Resistance to Insect Pests," *Plants*, vol. 7, no. 33, pp. 1–11, 2018, doi: 10.3390/plants7020033.

[16] J. F. Ma and N. Yamaji, "Silicon uptake and accumulation in higher plants," *Trends Plant Sci.*, vol. 11, no. 8, pp. 6–11, 2006, doi: 10.1016/j.tplants.2006.06.007.

[17] Z. Liang, L. Wang, and Q. Pan, "A New Recessive Gene Conferring Resistance Against Rice Blast," *Rice*, vol. 21, no. 47, 2016, doi: 10.1186/s12284-016-0120-7.

[18] C. H. Balachiranjeevi *et al.*, "Identification of a novel locus , BPH38 (t), conferring resistance to brown planthopper (Nilaparvata lugens Stal .) using early backcross population in rice (Oryza sativa L .)," *eUP*, vol. 215, no. 185, 2019, doi:

10.1007/s10681-019-2506-2.

[19] L. Yang, Y. Han, P. Li, L. Wen, and M. Hou, "Silicon amendment to rice plants impairs sucking behaviors and population growth in the phloem feeder Nilaparvata lugens (Hemiptera : Delphacidae)," *Sci. Rep.*, vol. 7, no. March, pp. 1–7, 2017, doi: 10.1038/s41598-017-01060-4.

[20] M. Rashid, M. Jahan, K. S. Islam, and A. Latif, "Ecological fitness of brown planthopper , Nilaparvata lugens (Stål), to rice nutrient management," *Ecol. Process.*, vol. 6, no. 15, pp. 1–10, 2017, doi: 10.1186/s13717-017-0080-x.

[21] A. Amtmann, S. Troufflard, and P. Armengaud, "The effect of potassium nutrition on pest and disease resistance in plants," *Physiol. Plant.*, vol. 133, pp. 682–691, 2008, doi: 10.1111/j.1399-3054.2008.01075.x.

[22] U. Kalapathy, A. Proctor, and J. Shultz, "An improved method for production of silica from rice hull ash," *Bioresour. Technol.*, vol. 85, pp. 285–289, 2002.

[23] S. Azat, A. V Korobeinyk, K. Moustakas, and V. J. Inglezakis, "Sustainable production of pure silica from rice husk waste in Kazakhstan," *J. Clean. Prod.*, vol. 217, pp. 352–359, 2019, doi: 10.1016/j.jclepro.2019.01.142.

[24] S. S. A. Be, Y. Y. Amasaki, and T. W. Akatsuki, "Assessing Silicon Availability in Soils of Rice-Growing Lowlands and Neighboring Uplands in Benin and Nigeria," *Rice Sci.*, vol. 23, no. 4, pp. 196–202, 2016, doi: 10.1016/j.rsci.2016.06.002.

[25] D. K. V Verma and P. P. S. Rivastav, "Proximate Composition , Mineral Content and Fatty Acids Analyses of Aromatic and Non-Aromatic Indian Rice," *Rice Sci.*, vol. 24, no. May 2016, pp. 21–31, 2017, doi: 10.1016/j.rsci.2016.05.005.

[26] N. S. Amalya, A. Yuniarti, A. Setiawan, and Y. Machfud, "The Effect of N , P , K Fertilizer and Nano Silica Fertilizer to Total N Content , N Uptake , and Black Rice Yield (Oryza sativa L . Indica) on Inceptisols from Jatinangor," *J. Plant Sci.*, vol. 8, no. 5, pp. 185–188, 2020, doi: 10.11648/j.jps.20200805.21.

[27] A. Nawaz and M. Farooq, *Rice Physiology*. Springer: Rice Production Worldwide, 2017.

[28] M. Rashid and M. Jahan, "Effects of Nitrogen , Phosphorous and Potassium on Host-Choice Behavior of Brown Planthopper , Nilaparvata lugens (Stål) on Rice Cultivar," *J. Insect Behav.*, 2016, doi: 10.1007/s10905-016-9594-9.

[29] Y. Chen, X. Rong, Q. Fu, B. Li, and L. Meng, "Effects of biochar amendment to soils on stylet penetration activities by aphid Sitobion avenae and planthopper Laodelphax striatellus on their host plants," *Pest Manag. Sci.*, no. May, 2019, doi: 10.1002/ps.5522.

[30] X. Zhang *et al.*, "Fitness cost of nitenpyram resistance in the brown planthopper Nilaparvata lugens," *J. Pest Sci. (2004).*, vol. 91, no. 3, 2018, doi: 10.1007/s10340-018-0972-2.

[31] F. A. N. Xue-ying, L. I. N. Wei-peng, L. I. U. Rui, J. Ni-hao, and C. A. I. Kun-zheng, "Physiological response and phenolic metabolism in tomato (Solanum lycopersicum) mediated by silicon under Ralstonia solanacearum infection," *J. Integr. Agric.*, vol. 17, no. 10, pp. 2160–2171, 2018, doi: 10.1016/S2095-3119(18)62036-2.

[32] Y. Han, P. Li, S. Gong, L. Yang, and L. Wen, "Defense Responses in Rice Induced by Silicon Amendment against Infestation by the Leaf Folder Cnaphalocrocis medinalis," *PLoS One*, pp. 1–14, 2016, doi: 10.1371/journal.pone.0153918.

[33] P. S. S. Sarao and J. S. B. Bentur, "Antixenosis and Tolerance of Rice Genotypes Against Brown Planthopper," *Rice Sci.*, vol. 23, no. 2, pp. 96–103, 2016, doi: 10.1016/j.rsci.2016.02.004.

[34] J. W. Jones *et al.*, "Toward a new generation of agricultural system data , models , and knowledge products : State of agricultural systems science," *Agric. Syst.*, vol. 155, pp. 269–288, 2017, doi: 10.1016/j.agsy.2016.09.021.

[35] T. Ruuska and P. Heikkurinen, "Domination , Power , Supremacy : Confronting Anthropolitics with Ecological Realism," *sustainability*, vol. 12, no. 2617, pp. 1–20, 2020.

[36] R. Bester, J. T. Burger, and H. J. Maree, "The small RNA repertoire in phloem tissue of three Vitis vinifera cultivars," *Plant Gene*, vol. 10, no. November 2016, pp. 60–73, 2017, doi: 10.1016/j.plgene.2017.05.009.

[37] L. Yang, Y. Han, P. Li, F. Li, S. Ali, and M. Hou, "Silicon amendment is involved in the induction of plant defense responses to a phloem feeder," *Sci. Rep.*, no. May, pp. 1–9, 2017, doi: 10.1038/s41598-017-04571-2.

[38] M. Jeer, K. Suman, T. U. Maheswari, S. R. Voleti, and A. P. Padmakumari, "Field Crops Research Rice husk ash and imidazole application enhances silicon availability to rice plants and reduces yellow stem borer damage," *F. Crop. Res.*, vol. 224, no. May, pp. 60–66, 2018, doi: 10.1016/j.fcr.2018.05.002.

[39] C. Seven, *New solutions using natural products*. Elsevier Inc, 2020.

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