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The exposure of manipulated insect sound towards rice seedlings grown through transplanting

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Abstract It is reported for the first time the effects of *Dundubia manifera* insect sound at a peak frequency of 4000 Hz toward the height of rice seedlings grown through the transplanting method. In addition, the rice productivity was determined through the yield of the rice crop. The rice planted was the *Situ Bagendit* variety consisting of the control (without sound exposure) and treatment (with sound exposure) groups. The results showed that the exposure of insect sound affected the height of the rice seedlings and the rice productivity. This was indicated by the height of the treated rice seedlings from the 7th to the 20th days after seeding (DAS), which was higher than the control group. The growth rates of the rice seedlings in the treatment and control groups were 2.0 cm/day and 1.6 cm/day, respectively. Furthermore, the yield of the treated rice seedlings increased by 35.42% compared to the control group.

Keywords: *Dundubia manifera*, Insect sound frequency, Rice seedling growth, Rice yields

Introduction

Rice is the main food source for the population of most Asian countries, especially Indonesia, which is the third largest rice producer in the world with a record of rice production reaching 70,600,000 tons per year. Rice fields on the Island of Java are the largest contributor to the supply of rice in Indonesia. In 2016 alone, Indonesia produced 79.14 million tons of rice, which was certainly in great demand by Indonesia's population of 237 million people. Meanwhile, with an increase in the population to 262 million people in 2017, rice consumption in Indonesia reached 114.6 kg per capita per year. Indonesia's Central Bureau of Statistics (BPS, 2019) reported that the national rice consumption in 2019 was 28.69 million tons. Moreover, the projection of rice production in Indonesia for the period of January to April 2022 was 25.4 million (Rahman, 2022). Despite having a high amount of rice production and a high level of rice consumption, Indonesia still becomes a rice importing

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country. In fact, the Indonesian government imported nearly 300,000 tons of rice in early 2018 to strengthen domestic rice reserves (BULOG, 2019). The countries that supply rice to Indonesia include Vietnam, Thailand, China, India, Pakistan, and the United States (BPS, 2019).

Those aforementioned facts show that Indonesia is facing problems with the sustainability of its rice production. This situation is caused by various factors, including the application of traditional agricultural techniques by farmers, the high demand for rice, and climate change due to global warming. Therefore, it is necessary to make breakthroughs, e.g. the provision of new machines and methods in agricultural technology, to achieve agricultural advancement and increase rice productivity in Indonesia. Technological supports are needed to obtain the best agricultural results, such as by using sound as a special treatment for plants to increase agricultural productivity (Frongia *et al.*, 2020; Hendrawan *et al*., 2020). In this study, the authors have developed the Audio Bio Harmonic (ABH) device. Each plant exposed to sound using the ABH device has a certain frequency response that affects plant growth and productivity. The best results for soybeans, shallots, peanuts, and potatoes are obtained at frequencies of 6000 Hz, 3000 Hz, 4500 Hz, and 4500 Hz with productivity of 0.018 kg/plant, 0.72 kg/plant, 0.53 kg/plant, and 0.87 kg/plant, respectively (Kadarisman and Purwanto, 2011). Furthermore, the ABH device is used to expose manipulated *Dundubia manifera* (*D. manifera*) insect sound upon plant seedlings. Other agricultural advancement efforts in the growth of plant seedling include the utilization of nanotechnology in the priming process of seedlings (Pereira *et al*., 2021a) and the technological advances in the selection of seedling varieties (Manangkil *et al*., 2020).

Various physical factors, such as exposure to light, can affect the seedlings growth of rice (*Oryza sativa* L.). According to Guo *et al*. (2011), the red-blue light emitting diode (LED) provides the best benefits for rice seedling cultivation. Blue LED significantly inhibits seedling height growth, while the red-blue LED causes the root length of the seedlings to shorten (Chen *et al.*, 2014). Other prior studies found that the growth of rice seedlings can be improved by using proline osmopriming (Pereira *et al.*, 2021b) and potassium nitrate and silicon oxide priming (Ali *et al*., 2021). However, studies on the effect of sound on rice seedlings are still very limited.

In this study, rice seedlings of the *Situ Bagendit* variety were exposed to the sound of *D. manifera* insect at a peak frequency of 4000 Hz in order to increase the rice productivity. The transplanting system (Kawatra *et al.*, 2021) of rice was used in this study. Thus, the objectives were to determine the effect of the manipulated *D. manifera* insect sound at a peak frequency of 4000 Hz on rice seedlings; and to determine the productivity of rice whose seedlings are exposed to the sound of *D. manifera* insect.

Materials and methods

The experiment was done by exposing the insect sound at a peak frequency of 4000 Hz using the ABH device upon the rice seedlings. The independent variable was the number of days after seeding (DAS), while the dependent variables were the seedlings' height and the rice productivity. The control variables were frequency (4000 Hz); planting media (fine muddy soil); rice variety (*Situ Bagendit*); nursery bed of 0.8 $\times$ 1.9 m^2 each spaced 0.2 m; and 700 m^2 of rice field. The study was carried out in the rice field in Karen Village, Tirtomulyo, Kretek District, Bantul Regency, Yogyakarta.

The rice seedlings were divided into two groups that are treatment and control groups with the same number of seedlings, i.e.: 50 seedlings. Each group consisted of five nursery beds. Hence, each nursery group was planted with 10 seedlings. The selection of these seedlings was conducted randomly. The treatment group was the seedlings exposed to the insect sound with a peak frequency of 4000 Hz, while the control group was those without sound exposure. This study applied the transplanting method where the set-up of the nursery beds can be seen in Figure 1.

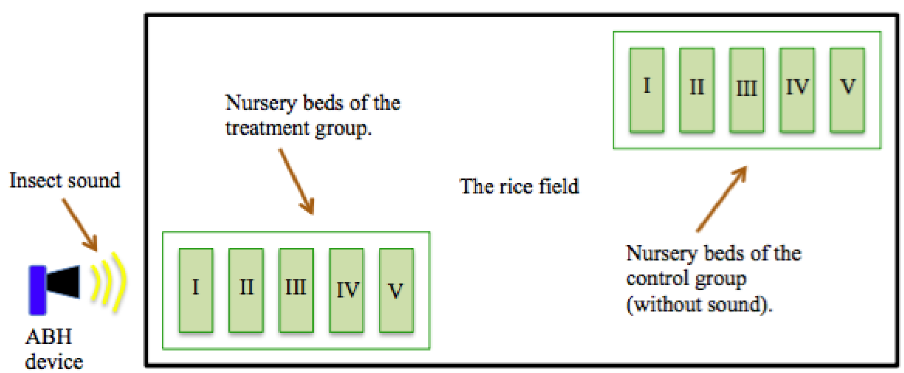

Figure 1. A schematic diagram of the nursery beds set-up in the rice field

The instruments used in this study were the ABH device with a manipulated *D. manifera* insect sound source, a charger, a plastic chair to place the ABH device, a ruler to measure the height of rice seedlings, and a balance to measure the rice productivity. Meanwhile, the materials used were rice seedlings, planting media, water, pesticides, and fertilizers.

The validation of the insect sound frequency was carried out before planting the rice seeds. This was done by recording the sound produced by the ABH device using a smartphone placed four meters in front of the device. Then, the obtained signal was processed using Adobe Audition CC 2017 software and Matlab R2016a software through the Fast Fourier Transform (FFT) method. Adobe Audition CC 2017 software was utilized to view waveforms and select insect sound signals. Furthermore, Matlab R2016a software was used to analyze the selected sound signal, so that the spectrum of the insect sound can be determined. From the insect sound spectrum, the peak frequency can be obtained.

The procedure of the experiment was as follows. The observations were made by selecting the planting media and finding the farmers who would provide the land, instruments, and time for this study. Then, seeding of the rice plants was done by spreading rice seedlings into the prepared nursery beds, which were divided into two groups, each with five plots of beds (see Figure 1). The rice seedlings were conditioned to be not fully underwater. Maintenance of rice seedlings was done by irrigating the nursery beds, applying fertilizers (organic, urea, and phosphate), and spraying insecticides on the seedlings. For the treatment group, the exposure of *D. manifera* insect sound at a frequency of 4000 Hz using the ABH device was carried out every day for one hour at 7 - 8 AM from the seedling's age of 5 until 20 DAS (See Figure 2). Next, the rice field was prepared for the planting media. Rice seedlings were transplanted at 20 DAS on the rice fields by separating the treatment and control groups. In this step, no sound exposure was performed. Maintenance of the rice plants was conducted by irrigating the rice field, applying fertilizers, and spraying insecticides on the rice plants. Finally, the rice plants were harvested after 12 weeks of planting.

Figure 2. A farmer is turning on the ABH device

The data were obtained by measuring the height of the rice seedlings in the treatment and control groups. In addition, data on rice productivity were achieved from the calculation of rice yields after harvest for both the treatment and control groups. In the analysis of rice seedlings' growth, data on the average values of the rice seedlings' height between the control and treatment groups were compared. Furthermore, the Origin software was used for linear fitting to obtain a linear function. From the linear fitting value, the slope (gradient) was obtained which indicated the growth rate of the seedlings' height. In addition, the rice yields of the treatment and control groups were compared.

Results

The selection results of the recorded portion of the sound produced by the ABH device in the time domain can be observed in Figure 3. The spectrum displayed in Figure 3 which was obtained through recording using a smartphone. It can be seen that the sound spectrum is in the form of periodic pulse waves.

The peak frequency of the pulse wave was obtained by using the FFT method. Based on the FFT results, the frequency ranged from 3850 Hz to 4150 Hz, and the peak frequency was obtained at a value of 4040 Hz with an intensity of 422.7 as observed in Figure 4.

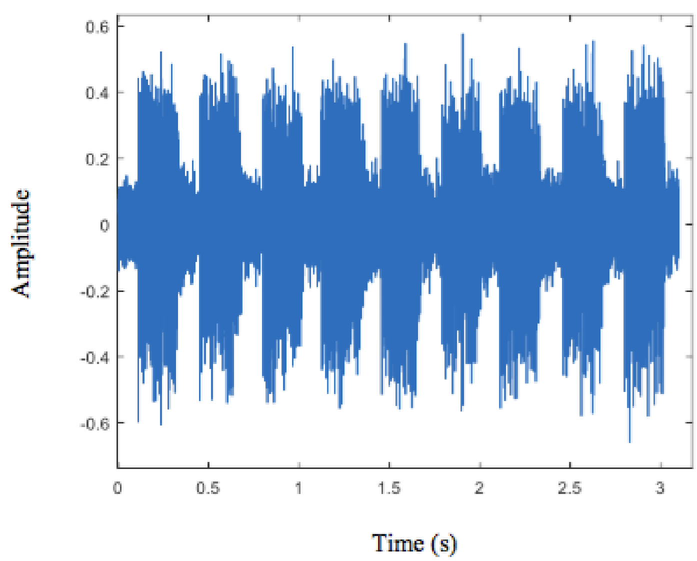

Figure 3. The sound waves of the manipulated *D. manifera* insect recorded using a smartphone in the time domain

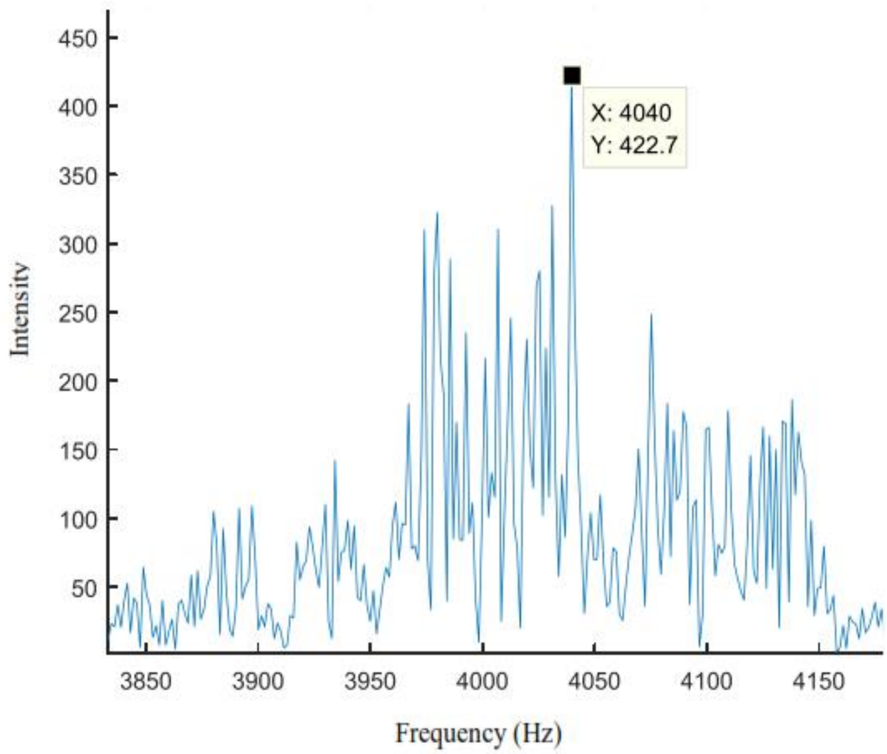

Figure 4. The spectrum of sound waves generated by the ABH device

The calculation results of the rice seedlings average height are shown in Figure 5. The first observation was made on the 5th day. Based on Figure 5, a difference in the height of the rice seedlings in the treatment and control groups was seen on the 7th day. On the 10th day, the difference increased to 3 cm. On the 20th day before the seedlings were planted, the height of the treated and control rice seedlings were 32.9 cm and 26.2 cm, respectively. It can be seen that the growth rate of the rice seedlings' height was linear with respect to DAS (Figure 5). The growth rate is indicated by the value of the slope or gradient on the average height graph. The greater the slope, the faster the growth rate of the seedlings. The growth rate of the treated and control rice seedlings has a slope of 2.0 cm/day and 1.6 cm/day, respectively.

The comparison between the data on the average height of the treated rice seedlings is shown in Figure 6. The height of the treated rice seedlings in this study at 16 DAS reaches 26.6 cm. It is clearly seen that the treated rice seedlings in this study is higher than the reference data for all DAS.

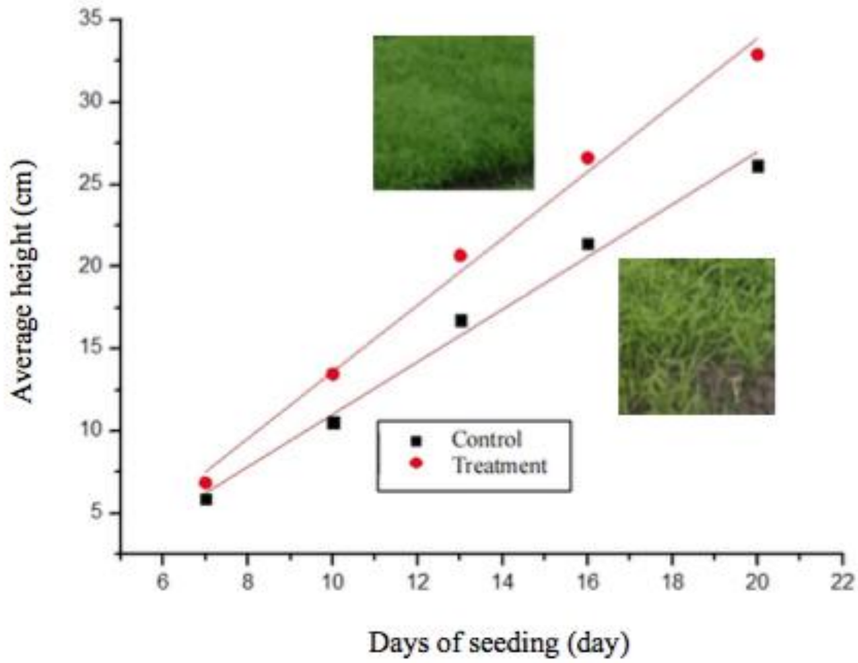

Figure 5. Rice seedlings' height of the treated and control groups

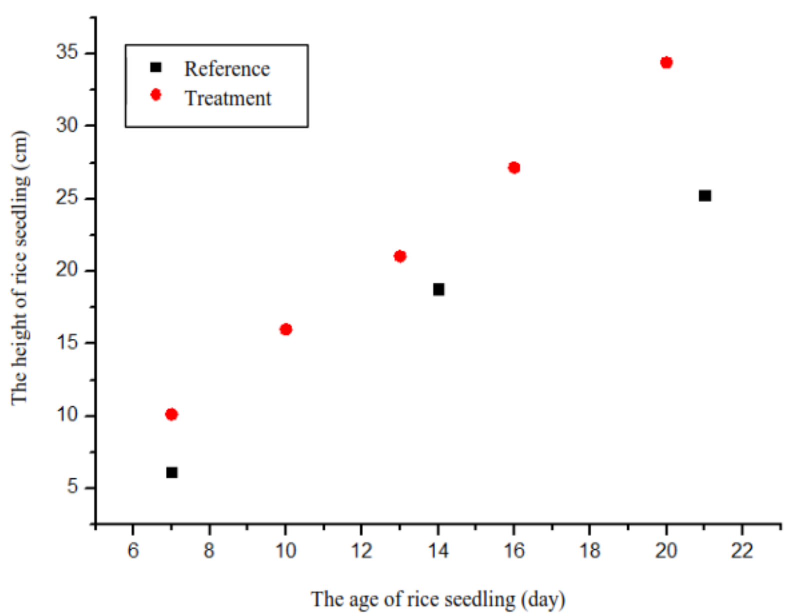

Figure 6. Height comparison between the treated rice seedlings

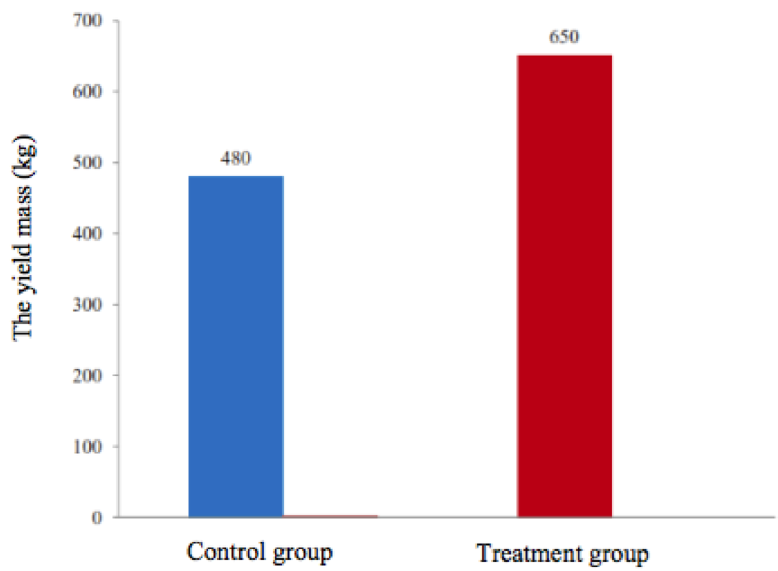

Figure 7. Comparison of rice yields between the control and treatment groups

The result of mass calculation of rice yields between the control and treatment groups is shown in Figure 7. The number of sacks obtained for the treatment group was 10 sacks of rice grain where each sack weighed 65 kg, meaning that the total yield was 650 kg. Meanwhile, the number of sacks obtained for the control group was 8 sacks of rice grain where each sack weighed 60 kg, hence the total yield was 480 kg.

Discussion

The sound waves exposed to the rice seedlings are generated by the ABH device. The sound source is the manipulated *D. manifera* insect sound, tuned to a frequency of around 4000 Hz. The validation of the sound frequency originating from the ABH device is expected and required. Therefore, the *D. manifera* insect sound coming from the ABH device was recorded using a smartphone. Furthermore, the peak frequency of the spectrum was obtained at 4040 Hz, which did not reach precisely 4000 Hz. This may be due to ambient noise, such as wind and bird sounds. However, this frequency was still quite close to 4000 Hz. Therefore, the peak frequency of around 4000 Hz was achieved. This is in accordance with a study by Rosana *et al.* (2019), which stated that the exposure of insect sound at a frequency of 4000 Hz affects the opening of stomata in rice plant, thus helping the rice plant to absorb nutrition especially during the photosynthesis process.

This study applies the transplanting system, in which the rice seedlings are grown in nursery beds for 25 to 30 DAS (Kawatra *et al.*, 2021; Basir *et al.*, 2021). Then, they are ready to be transplanted on the rice field using manual labor or machine and maintained for approximately three months. According to Syamsiah and Asih (2019), the parameter, which determines the readiness of rice seedlings to be transplanted, is the plant's height. Rice seedlings with a height ranging from 9.8 to 12.7 cm are suitable for machine transplanting (Kim *et al*., 1999). Therefore, transplanting is a suitable way to study the effect of insect sound exposure towards the growth of the rice seedlings. The treated rice seedlings are seen to be higher than the control rice seedlings, with a difference of 6.7 cm at the 20th DAS. Moreover, the overall growth rate of the treated rice seedlings is proved to be greater than the growth rate of the control rice seedlings. These results indicate that the exposure of the manipulated *D. manifera* insect sound at a peak frequency of 4040 Hz affects the height of the rice seedlings. The difference in height between the seedlings of the treatment and control groups is quite significant, which starts around the 10th day and continues to increase until the 20th day. This means that the sound exposure gives a positive effect on the growth of the rice seedlings. This is also supported by the height comparison of the treated rice seedlings with the reference data obtained from a previous study by Syamsiah and Asih (2019).

The height of rice seedlings, which is ready to be transplanted, is in the range of 22 cm to 25 cm, or after 20 days of seeding (Idawanni, 2015). In this study, the treated rice seedlings could be transplanted before the 16th DAS because the average height has already reach more than 25 cm. According to Kim *et al.* (1999), rice seedlings can be transplanted as early as the 10th day, indicating the possibility of a faster transplantation of rice seedlings, hence a faster harvest. The top and bottom insets of Fig. 5 show the treated and control rice seedlings. It is clearly seen that the treated rice seedlings are denser than those of the control group.

The exposure of insect sound is only conducted on the rice seedlings in the nursery beds. This means that from the time the rice seedlings are transplanted until they are harvested, there is no sound exposure. Therefore, we can observe the effect of the insect sound exposure towards the rice plants during planting (without sound exposure) by determining the rice yields after harvest. The rice yields from the treated rice seedlings are increased by a percentage of 35.42% compared to the control group. This clearly indicates that the sound exposure, which is only applied to the rice seedlings in the nursery beds, can increase the rice yields. The increase in the rice yields increases the rice productivity (Bhatt *et al*., 2021).

It is extensively accepted and proven via various experiments that acoustic wave or sound vibration (SV) affects plants. However, the mechanism in which SV affects plants is still an ongoing study to date. Physically, as a mechanical wave SV is attenuated by plants in three possible ways, i.e.: reflection, scattering, and absorption by the steam, branch, and/or leaf of the plants (van Renterghem *et al*., 2012). We believe that these physical processes affect the physiology of the plants. One example of this, which is in accordance to our school of thought, is that SV can tune the opening or closing of stomata (Kadarisman and Purwanto, 2011; Suryadarma *et al*., 2020; Hassanien *et al.*, 2014). In this case, the wider the stomata opens, the higher the amount of carbon dioxide (CO_2) that may enter the stomata, hence the photosynthesis rate can increase (Baldocchi, 1997). Many parts of plants can also be affected by SV, such as the tissue (Qin *et al*., 2003); root (Fernandez-Jaramillo *et al.*, 2018); enzyme metabolism (Li *et al*., 2008); and genes (Xiujuan *et al*., 2003). Interestingly, in this study, although the SV exposure is only conducted upon the rice seedlings, it still affects the rice yields. Hence, the SV might have long lasting effect on plants beyond the SV exposure period. In relation to the stomata, the SV exposure upon the seedlings may have a lasting effect that even after the SV exposure has been stopped the stomata becomes more susceptible to the surrounding sound with the same frequency. Furthermore, it may also happen that the SV exposure upon the seedlings activates enzyme metabolisms and/or genes that lasted during planting until harvest time.

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