Effect of plant sound wave technology to increase productivity of mustard greens (Brassica juncea L.)

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Abstract. Plant sound wave technology (PSWT) is the use of sound waves to improve crop productivity and quality through optimization of stomata opening so that plants are able to absorb nutrients and water optimally. The purpose of this study is to test PSWT to increase the vegetative growth of mustard greens (Brassica juncea L.). The type of music used in PSWT is Javanese gamelan entitled Puspawarna. PSWT exposure time is given to plants in the morning and evening. The frequencies used are 3-5 kHz, 7-9 kHz, and 11-13 kHz. The mixture of organic planting media i.e. roasted husk, cocopeat, and moss with a ratio of 2: 2: 1 for soil, organic planting media, and organic fertilizer. Observations were made on plant height, plant length, wet weight, stomata opening, leaf chlorophyll, leaf area, and the number of plant leaves. The results showed that the frequency and the mixture of organic planting media significantly affected the wet weight, plant length, stomata opening, leaf chlorophyll, leaf area, and the number of plant leaves. The best PSWT method for growing mustard greens is using a frequency of 3-5 kHz with moss as the organic planting media. The maximum yield of vegetative growth resulted in the most optimal stomatal openings of 70.84–159.46 µm, with a plant height of 19.47 cm, plant length of 29.47 cm, leaf area of 31.99 cm², number of leaves is 5.33 strands, leaf chlorophyll of 31.60 cci, and wet weight of 5.01 g.

1. Introduction
Mustard greens (Brassica juncea L.) are a type of vegetable that has high economic value and are the most popular among all groups of people. According to [1], the demand for mustard greens showed an increase. Mustard greens contain various nutrients, the contents contained in mustard greens are protein, fat, carbohydrates, Ca, P, Fe, vitamin A, vitamin B, and vitamin C [2]. Because of the large increase in demand for mustard greens, conventional cultivation is not sufficient to meet those needs. It is because conventional cultivation requires a long time. In addition, the limitations of the planting media become an obstacle to the diversity of commodities in a narrow area, so it has an impact on agricultural output with suboptimal productivity. The abundance of organic material has the potential to be an alternative to farming. Organic matter has the potential to store water and is rich in air pores so that it can stimulate root growth quickly and dense [3][4].

One technology that is developing to increase crop productivity is plant sound wave technology (PSWT) [5][6]. Provision of exposure to sound waves with a certain frequency has been proven effective for the optimal opening of leaf stomata, so that water absorption and nutrition also take place...
optimally. The use of organic planting media also affects plant growth. The selection of the right organic planting media can also stimulate plant growth optimally [7]. There has never been a study that discusses the combination of methods for choosing the type of organic planting media with the use of PSWT.

PSWT is a technology that combines the effects of acoustic frequencies to increase osmotic pressure in guard cells so that they can vibrate the particles, especially the Mg element contained in chlorophyll \((\text{C}_{55}\text{H}_{72}\text{O}_{5}\text{N}_{4}\text{Mg})\). PSWT which is produced by music can stimulate the opening of stomata and affect the movement of CO\(_2\) around the plant so that it can affect the absorption of water, nutrients, and CO\(_2\) around the leaves. Based on previous research shows that the use of PSWT gives better results than plants without using PSWT [8][9]. The purpose of this study was to examine the effect of PSWT and the choice of organic planting media on the vegetative growth of mustard greens.

2. Materials and Method

The research was carried out in the Mechatronic Laboratory of Agro-industrial Tools and Machinery, Department of Agricultural Engineering, Faculty of Agricultural Technology, Brawijaya University, Indonesia. The tools used in this study include: 1) growth chamber with artificial environments (size of 100 × 150 cm) to reduce noise from the outside environment; 2) advance duo 050 speaker (3 watts 4 ohms) as a sound source; 3) RTC DS3231 used to control the timing of sound exposure; 4) relay 4 channel 5 volts which is used to turn on / off the speaker digitally; 5) AC to DC 12 V 10 A power supply as a power source; 6) arduino uno atmega as a microcontroller to run automation; 7) MP3 Decoder 5 volt (mono speaker) as a sound generator; 8) a ruler which is used to measure height and length of mustard greens; 9) sound level meter (Extech Instruments) used to measure sound levels; 10) polybag size 9/18 x 18 as a medium for planting mustard greens; 11) hygrometer (Anymetre model: TH108) for measuring air humidity; 12) thermometer (Anymetre model: TH108) for measuring the temperature level of the observed environment; 13) lux meter (Taxi 8720) for measuring the intensity of environmental light condition; 14) chlorophyll meter (SPAD-502Plus) used to measure chlorophyll or leaf green index; 15) digital scales (I-2000 Camry) used to measure leaf area and leaf wet weight; and 16) Olympus binocular CX43 microscope used to observe stomata openings. The materials used in the study are: 1) mustard greens seeds; 2) organic fertilizer as soil organic matter and nutrients for plants; 3) soil, roasted husk, cocopeat, and moss as mixture planting media; 4) organic liquid fertilizer for plant nutrition during growth; and 5) clear nail polish which is used for leaf stomata attachment media to measure the opening of leaf stomata.

In this study, three growth chambers (150 × 100 cm) was used with a wall made of 0.5 mm thick UV palette placed in a screen house. In the chamber, there are two speakers placed in the top center, the speakers face down toward the plant. The sample used was 7 days old mustard greens seedlings. Furthermore, PSWT with a various mixture of planting media was given for 24 days, in the morning at 07.00-10.00 and evening at 14.00-17.00. The planting media used in the cultivation of mustard greens in this study uses a mixture of planting media (roasted husk, cocopeat, and moss), soil, and organic fertilizer in a ratio of 2:2:1. The observations were conducted to measure the physical development of mustard greens i.e. plant height, plant length, number of leaves, leaf area, wet weight, leaf chlorophyll, and stomata openings.

In this study traditional Javanese gamelan music entitled "Puspawarna" was utilized. The frequency has been set using the Audacity application. There are two factors in the study i.e. the frequency level of 3-5 kHz, 7-9 kHz, and 11-13 kHz; and the second factor is the mixture of organic planting media (roasted husk, cocopeat, and moss). The treatment was carried out three iterations and there were control plants as a comparison in this study so that the total sample was 30 plants. Environmental factors in the screen house have been uniformly and stably conditioned during the growth of mustard greens i.e. temperature, humidity, light intensity, and sound intensity.
3. Results and Discussion

From the measurement of environmental conditions both inside and outside environment, the results showed the temperatures range from 28-32 °C and average air humidity around 40-50%, the intensity of sunlight ranging from 230 to 270 ×10² lux. The results of the mustard greens growth using PSWT can be seen in Figure 1. The measurements were carried out in the morning and evening when the plants were treated. The level of noise from each treatment ranged from 68-76 dB while for external environmental conditions, the noise level ranged 55-57 dB. The pH level of nutrients shows a value of 5.5–6.5, the pH value is not much different from the growth requirements of mustard greens, which is around 5-7. This is in line with [10] that in nutrient solutions that have a pH value with an optimal range, nutrients will become soluble so that they can be utilized by plants. The treatment of various types of planting media with the addition of nutrients provides a real interaction with the productivity parameters of mustard greens, this is due to the suitability between the nutritional treatment and the planting media used, and the appropriate environmental conditions.

![Figure 1](image1.png)

**Figure 1.** The result of mustard greens using PSWT
The plant height observation data, it is known that mustard greens at frequencies of 3-5 kHz with moss planting media have the best results, as can be seen in Figure 2 with a plant height value of 19.47 cm. In the treatment of cocopeat planting media, the plant height was 14.50 cm. The lowest value was found in roasted husk planting media with the plant height values of 13.73 cm. Whereas at the frequency of 11-13 kHz using roasted husk planting media produces the lowest average plant height of 12.53 cm. Based on statistical analysis, frequency and mixture of planting media significantly affected the height of mustard greens. From the further DMRT tests, it can be concluded that the most significant effect is frequency 3-5 kHz using moss planting media.

**Figure 2.** The relationship between treatment (frequency and planting media) and plant height

The results of plant lengths, the frequencies of 3-5 kHz have the best effect compared to other frequencies. The results of plant length showed a value of 29.47 cm when using moss planting media, while at the frequency of 11-13 kHz with roasted husk planting media have the lowest plant lengths value of 21.53 cm. Figure 3 shows the relationship of frequency and planting media to the length of the mustard greens.

**Figure 3.** The relationship between treatment (frequency and planting media) and plant length

The result of the leaf area, the highest average value is at the frequency of 3-5 kHz using moss planting media with a leaf area of 31.99 cm². While the lowest average value is found at the frequency of 11-13 kHz using roasted husk planting media with a leaf area of 10.43 cm². Figure 4 is a graph of leaf area with replications that have been averaged between each treatment. Frequency and planting media have a significant effect on the leaf area of mustard greens, this can be proven in the ANOVA test results using a real level (α = 0.05) that the frequency treatment has sig. (α = 0.006) and the use of planting media has sig. (α = 0.000) where this shows that both treatments are < (α = 0.05). Leaf area results showed that PSWT exposure gave better results than control plants. It is because the vibrations or waves caused by PSWT are thought to be able to change the metabolic activity of cells to enable cells to transfer compounds such as amino acids and ATP. In addition to the plant height and number
of leaves, the increase in fresh weight is also affected by the leaf area and leaf chlorophyll. The greater the leaf area and the more amount of chlorophyll the photosynthesis will run effectively.

![Leaf area comparison](image)

**Figure 4.** The relationship between treatment (frequency and planting media) and leaf area

The highest average value of the number of leaves is at a frequency of 3-5 kHz using moss planting media with the number of leaves of 5.33 strands, while the lowest number of leaves is at the frequency of 11-13 kHz using roasted husk planting media with the number of leaves of 4 strands. Figure 5 is a graph of the number of leaves. From the statistical analysis, frequency and planting media have a significant effect on the number of mustard greens leaves, this can be proved in the ANOVA test results using a real level ($\alpha = 0.05$) that the frequency treatment has sig. ($\alpha = 0.734$) and the use of planting media has sig. ($\alpha = 0.021$) which shows that both treatments are $< (\alpha = 0.05)$. Then in further tests DMRT with a 5% significance level that the best frequency treatment is 3-5 kHz which has an average number of leaves of 4.89 strands and moss planting media which has an average value of 5.22 strands.

![Number of leaves comparison](image)

**Figure 5.** The relationship between treatment (frequency and planting media) and the number of leaves

The leaf chlorophyll data, it is known that the highest average values are at frequencies of 3-5 kHz and moss planting media with leaf chlorophyll amount of 31.60 cci. While the lowest average value is at the frequency of 11-13 kHz and roasted husk planting media with leaf chlorophyll amount of 24.50 cci. Figure 6 is a graph of leaf chlorophyll observation results in each treatment. From the ANOVA statistical analysis test, it is known that the frequency and planting medium significantly affect the amount of leaf chlorophyll.
Figure 6. The relationship between treatment (frequency and planting media) and leaf chlorophyll

Figure 7. The relationship between treatment (frequency and planting media) and wet weight

In the observation of the wet weight of mustard greens, the highest average values were found at a frequency of 3-5 kHz and the moss planting medium with a wet weight of 5.01 g. Then for the lowest
average value found at a frequency of 11-13 kHz and roasted husk planting media with a wet weight of 2.26 g. Figure 7 is a graph of the wet weight of mustard greens between each treatment. ANOVA statistical analysis test results on the frequency treatment and planting media significantly affected the wet weight of mustard greens.

Stomata are the most important part of plants because stomata have a function as a place of respiration. PSWT can stimulate the opening of the stomata more optimally [11]. In the results of this study, the widest stomata aperture is at a frequency of 3-5 kHz that is equal to 70.84-159.46 µm, while at a frequency of 11-13 kHz produces a stomata opening of 67.88-148.77 µm, and for mustard greens without PSWT it produces 61.29-86.29 µm of stomata openings. The results of enlarged stomata can be seen in Figure 8.

4. Conclusions
Based on the research results it is known that plant sound wave technology (PSWT) can increase the productivity and quality of mustard greens. The best results are on the 3-5 kHz frequency. The best planting media is using moss. This can be seen in the observation of plant height using moss planting media which has a value of 19.47 cm. The best length of mustard greens is 29.47. The best leaf area is 31.99 cm². The number of leaves with the highest average is 5.33 strands. The amount of leaf chlorophyll with the highest average value is 31.60 cci. Wet weight with the highest average value is 5.01 g. The most optimal stomata opening was in the range of 70.84-159.46 µm.

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