Pertanika J. Sci. & Technol. 28 (1): 69 - 90 (2020)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

The Effect of Javanese Gamelan Music on the Growth of Chinese Broccoli

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ABSTRACT

Plant acoustic frequency technology (PAFT) is a technology that utilizes sound waves in the form of frequencies within the audiosonic threshold. The purpose of this study was to test PAFT by using Javanese gamelan music entitled puspawarna on the productivity of vegetative growth in Kailaan (*Brassica alboglabra*) plant. PAFT exposure time was given to plants during the morning and evening. The frequencies ranged in 3-5 kHz, 7-9 kHz and 11-13 kHz. In addition, sound exposure times were for 1 hour, 2 hours and 3 hours. Based on the statistical analysis, the results indicated that the frequency and sound exposure time had a significant effect on plant wet weight, plant length, and stomata openings. The best frequency for Kailaan plant growth was in 3-5 kHz with the best exposure time of 3 hours. The combination of frequency and sound exposure time resulted in the most optimal stomata openings (stomata diameter at the top of the leaves of 89.19 ~ 93.45 µm and stomata diameter at the bottom of the leaves of 136.69 ~ 140.74 µm) with chlorophyll of 80.86 chlorophyll content index (cci), plant length of 47.33 cm, plant wet weight of 84 g, area of leaves of 207.06 cm^2, plant height of 9.4 cm, and number of leaves of 11 strands.

Keywords: Frequency, kailaan, PAFT, sound exposure time

ARTICLE INFO

Article history:
Received: 1 August 2019
Accepted: 15 November 2019
Published: 13 January 2020

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ISSN: 0128-7680
e-ISSN: 2231-8526

INTRODUCTION

Kailaan (*Brassica alboglabra*) is one of the green leafy brassicas which are widely grown for commercial production in East and Southeast Asia. Kailaan or Chinese broccoli is one of the most important leafy vegetables grown in Southeast Asia (Sagwansupyskorn, 1993). Plants can adapt to tropical lowland heat and humidity which can be planted throughout the year. Several benefits for tropical farmers include short harvest duration, low production costs compared to many other vegetable crops, ease of seed production, and Kailaan easy adaptation (Hanson et al., 2004). Commercial production of Kailaan is usually concentrated close to the city due to the characteristics of plants such as: fragile, easily damaged, and short shelf life that requires a production location adjacent to the market (Hanson et al., 2011). Kailaan has shiny blue-green leaves with thick crispy stems. This plant is harvested commercially when blossoming buds have been formed but are not yet open (Okuda, 2000).

In its growth, vegetable plants adjust to environmental factors including light, temperature, moisture, and mechanical perturbations such as: wind, rain, and touch. Several methods of vegetable cultivation have been developed to optimize productivity and quality of vegetable crops. One effective method is the manipulation of environmental factors in which vegetables are cultivated (Rouphael et al., 2018; Hendrawan et al., 2019; Umam et al., 2019). Modern greenhouses are designed and equipped with sensors and automatic control systems to adjust air temperature, root zone temperature, light intensity and quality, relative humidity and carbon dioxide (CO_2) concentration, according to plant needs and vegetative growth stages (Graamans et al., 2018). Scientific literature deals with the importance of temperature control for vegetable quality. Max et al. (2009) postulated the effect of temperature regulation on plant quality reporting that the air conditioning system in a polyethylene-covered greenhouse reduced the incidence of rot at small flower ends and fruit, and increased Ca content. Setting the temperature in the root zone is as important as in the room temperature, which provides effective effect on the growth of vegetable plants (Urrestarazu et al., 2008). Artificial lighting conditions in greenhouses play an important role for vegetable quality in terms of visual, organoleptic properties and chemical composition. According to Li and Kubota (2009) and Lin et al. (2013), the application of variable quality supplemental light (UV-A, blue, green, red and far red, and white LED diodes) causes significant differences in phytochemical content (anthocyanins, carotenoids, chlorophylls and flavonoids) from lettuce leaves, hence light additional can be a modulator of useful phytochemical content. Setting the intensity of light in a controlled environment is also essential which affects the photosynthetic activity and chemical composition in vegetables (Kyriacou et al., 2016; Ksas et al., 2015). Addition of CO_2 up to 1000-1200 µmol mol^{-1} in the greenhouse also has a significant effect to increase vegetable productivity up to 30% and increase the quality of vegetable crops both in terms of chemical composition, antioxidant activity, fiber content, vitamin C, protein, organic acids, fat, and sugar content (total, reducing, and non-reducing) (Chalabi et al., 2002; Becker & Klaring, 2016; Sgherri et al., 2017; Baslam et al., 2012; Khan et al., 2013). The regulation of environmental humidity (RH) of vegetable cultivation also has a significant effect on the productivity and quality of vegetable products (Vanhassel et al., 2015; Leyva et al., 2014). High RH results in heat damage due to reduced evapotranspiration rates, while at the same time reducing sap flow through phloem reduction and ion translocation in plant tissues, which produces symptoms of nutrient deficiencies. Among the environmental factors that have been mentioned (temperature, light and humidity), it is revealed that plants also respond to sound waves that can stimulate growth increasing productivity and immune systems in plants (Mishra et al., 2016; Chowdhury et al., 2014). Research on the effect of sound waves on plant growth has been unfortunately limited.

To date, there are still inadequate studies that focus on the use of plant acoustic frequency technology (PAFT) to increase the productivity and quality of Kailaan vegetables. PAFT aims to provide exposure to sound waves in plants under specific frequencies in accordance with the plant's meridian system to increase crop production and reduce fertilizer use (Meng et al., 2012; Collins & Foreman, 2001). Sound waves are roughly classified into three regimes by its frequency: infrasound (10^{-4}–20 Hz), audible sound (20×10^{4} Hz) and ultrasound (2×10^{4}– 10^{12} Hz). Several studies have proven that the application of audible PAFT is beneficial for plant growth, especially in vegetables (Hassanien et al., 2014; Jaramillo et al., 2018; Pujiwati & Djuhari, 2014; Ankur et al., 2016; Weiming et al., 2015). PAFT has been applied at various stages of plant physiological growth, such as: in seed germination, callus growth, endogenous hormones, photosynthetic mechanisms, and transcription of certain genes. Good stimulation can increase disease resistance and can reduce the use of chemical fertilizers and biocides (Zhao et al., 2002). The utilization of PAFT can also regulate the quality of plant products extending the shelf life (Kim et al., 2018). Plants can spontaneously produce sound waves at relatively low frequencies of 50-120 Hz. In addition, plants similar to humans and other animals have internal sound frequencies. Plants can also absorb and resonate with certain external sound frequencies (Hou et al., 1994; Hou & Li, 1997). Sound waves can change cell cycles (Wang et al., 1998). Sound waves vibrate the leaves of plants and accelerate protoplasmic movements in cells (Gagliano et al., 2012). Based on the facts about the advantages of PAFT, there is possibility that PAFT can improve the production of Kailaan as the most important vegetables in Southeast Asia. Furthermore, there has been no research which observe the effectiveness of PAFT for Kailaan growth.

The purpose of this study is to apply PAFT for the vegetative growth of Kailaan vegetables. The sound utilized as PAFT is derived from traditional Javanese music, with the Javanese Gamelan entitled Puspawarna. In previous studies, it has been proven the effectiveness of Javanese gamelan music compared to other types of music such as rock and jazz (Hendrawan et al., 2018). The results showed that PAFT effectively increased vegetative growth of plants. The results for each type of music i.e. jazz, gamelan, and heavy metal were as follows: plant height of 14.84, 15.96, and 15.3 cm, respectively; leaf area of 13.9, 29.38, and 26.01 cm^2, respectively; plant root dry weight of 0.156, 0.244, and 0.238 g, respectively; plant length of 16.12, 18.74, and 19.5 cm, respectively; and plant wet weight of 1.94, 2.78, and 2.384 g, respectively.

MATERIAL AND METHODS

This research was conducted at the Agroindustry Tools and Machinery Mechatronics Laboratory, Department of Agricultural Engineering, Faculty of Agricultural Technology, Brawijaya University, Malang, Indonesia. The utilized tools in this study can be seen in Table 1.

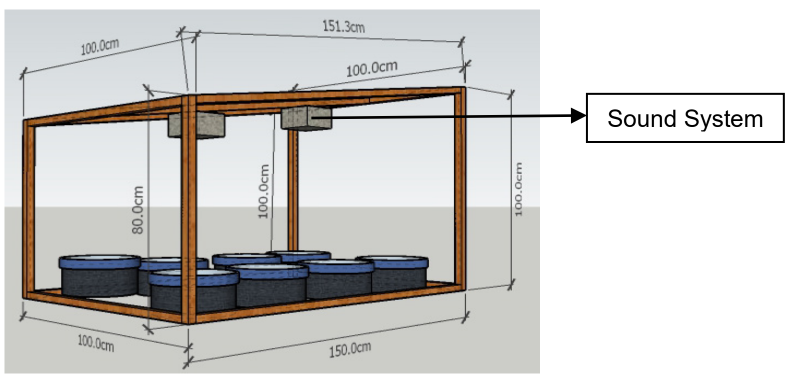
Table 1
The utilized tools in the study

Device	Specification	Function
Growth chambers	there were three growth chambers used, each chamber was coated with ultraviolet (UV) plastic with a thickness of 0.15 to 0.2 mm	as a place for Kailaan cultivation
Portable Speaker	Advance duo 050 speakers (3 watts, 4 ohms, 20 Hz ~ 20 kHz frequency response)	as a sound source
Digital timing module	DS3231 RTC	to control the timing of sound exposure
Relay	4-volt 4 channel relay	to turn on and off the speakers with digitally
Power Supply	AC to DC 12 V10 A Power Supply	as a power source
Microcontroller	Arduino uno atmega	as a microcontroller for control systems
Mono speaker	5-volt MP3 decoder	as a sound generator
Sound level meter	Extech Instruments	to measure sound noise levels
Chlorophyll Meter	SPAD-502Plus	to measure chlorophyll or green leaf index

Table 1 *(Continued)*

Device	Specification	Function
Digital Scales	(I-2000) and (Camry)	to measure leaf area and wet weight
Microscope	Olympus CX43 Binocular Microscope	to observe the diameter of the stomata opening

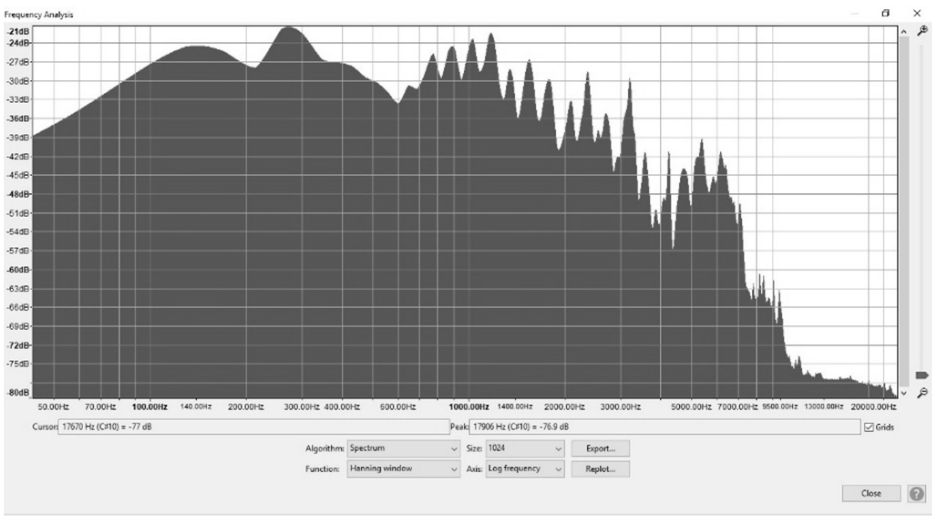
This study utilized the three chambers in a greenhouse measuring of 150 x 100 cm where each chamber had two speakers placed at the top center facing down towards the plant as shown in Figure 1. The treatment chamber was placed in a greenhouse that had been tested to be soundproof and was far from crowded. The distance of each chamber was



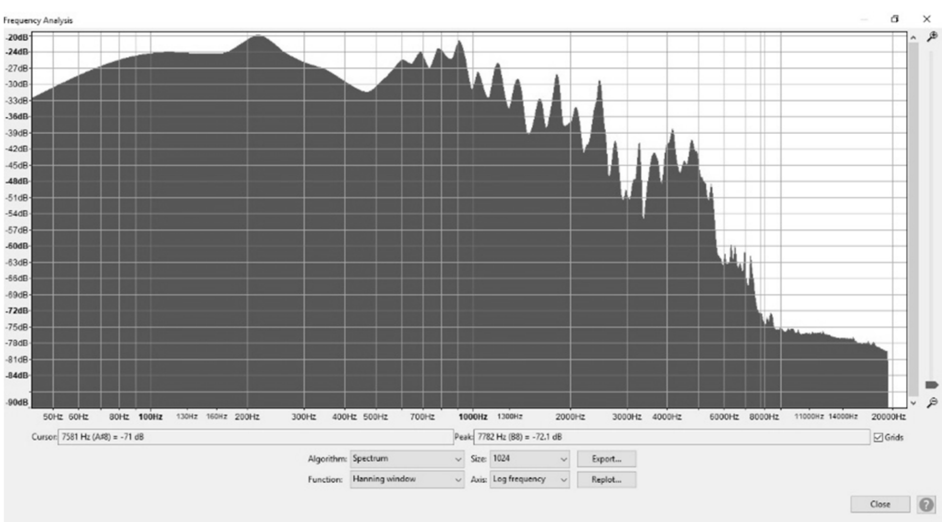
(a)

(b)

Figure 1(a) & (b). PAFT design in a cultivation chamber set far enough from one another, so there was no noise inside the chamber. Before the study begin, each chamber was subjected to a soundproof test. Each chamber represented one frequency treatment. In the first hour treatment of PAFT exposure, all plants were in each growth chamber. At the second hour, a set of plants was removed away from each chamber. At the third hour, another set of plants was removed away from each chamber. After PAFT treatment was complete, all plants were returned to the chamber. Measurement result of environmental temperature both inside and outside the observation environment ranged from 28-32 °C and air humidity ranged from 40-50%. The measurements were conducted in the morning and evening when the plants were treated. Whereas, the sound intensity level from each treatment ranged from 68 to 76 db (Pujiwati et al., 2018; Hassanien et al., 2014). The utilized sample was Kailaan vegetable seedlings which had aged 20 days after seedling. PAFT treatment was performed for 24 days in the morning at 07.00-10.00 a.m and in the afternoon at 02.00-05.00 p.m. Based on previous research, the best stomata openings were in the morning and afternoon. Because during the daytime the evaporation rate was high, so the stomata would automatically close to reduce the rate of evaporation. At the end of the study, the Kailaan plant age was 44 day after seedling. Water and nutrition were given evenly and equally for all research treatments. Water was given to plants every morning (07.00 a.m) and in the afternoon (05.00 p.m) with a dose of 40-50 mL for each water supply. The nutrition provided was a mixture of vermicompost and soil in a ratio of 1: 1. Plants that had been sown for 15 days were then transferred to a polybag with a mixture of vermicompost (25 kg) and soil (25 kg). Apart from giving vermicompost, nutrients were also given to plants in the form of organic liquid fertilizer 10 mL every 3 days at 07.00 a.m and 02.00 p.m. The sound applied as PAFT treatment was derived from Javanese Gamelan music entitled Puspawarna whose frequency had been set by using the Audacity application. The Javanese gamelan acoustic was taken directly from the recording process of a Javanese gamelan music. From the music data that had been taken, then the sound was corrected to eliminate noise and the frequency was adjusted to 3-5 kHz, 7-9 kHz, and 11-13 kHz using audacity software. The results of measurements in each level of frequency were illustrated in Figure 2. The frequency range shown in Figure 2 (3-5 kHz; 7-9 kHz; and 11-13 kHz) were applied in this study as frequency treatments. Determination of treatment was based on preliminary research (Hendrawan et al., 2018). From preliminary research, this study was recommended to apply the frequency level variation (Hassanien et al., 2014) ranging in 3-5 kHz, 7-9 kHz, and 11-13 kHz. The second treatment factors included sound exposure time (Pujiwati & Djuhari, 2014) for 1 hour, 2 hours, and 3 hours. The control plants as a comparison in this study were Kailaan plants without PAFT treatment. In this study, each treatment used five plants, so that the total plants used were 50 plant samples. However, from these samples only three samples were selected that were the best for each treatment. Environmental factors in the greenhouse had been optimally conditioned for the growth of the Kailaan plant conveying: temperature control, air humidity, sound intensity, and light intensity. The PAFT test results were performed on several vegetative aspects of Kailaan plants, including: amount of chlorophyll / chlorophyll content index (cci), plant length (cm), plant wet weight (g), leaf area (cm^2), plant height (cm), number of leaves (strands), and stomata opening diameter (µm) at the top of the leaf and at the bottom of the leaf. The measurement of plant height was performed by measuring plant height starting from the base of the stem which was parallel to the surface of the planting medium to the base of



(a)



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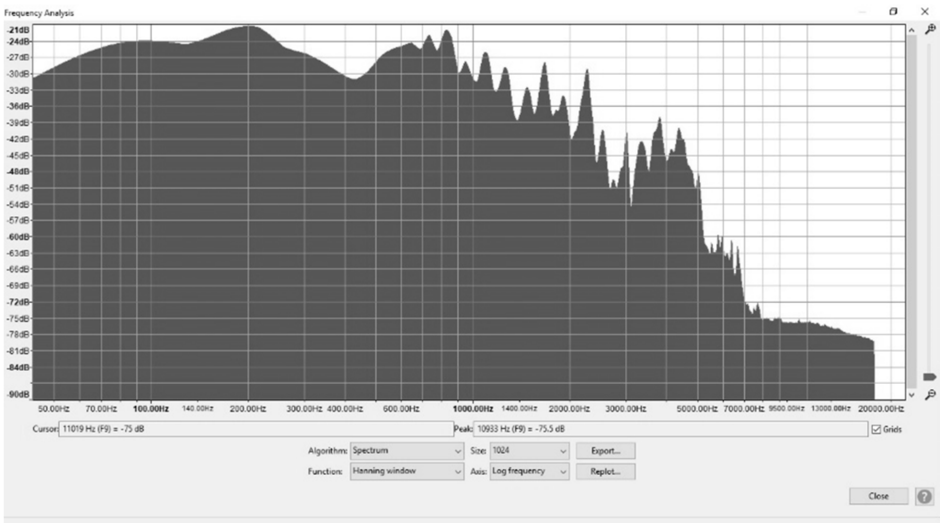

(c)

Figure 2(a), (b) & (c). Analysis of frequency measurements by using Audacity

the plant stem. The measurement of plant height was conducted for every 3 days, starting from the 3rd day until the plants were 24 days old. The number of leaves was measured by selecting and counting each leaf of Kailaan plant. The selected leaves included the leaves that have begun to open until the leaves widely open; thus, leaves which were facedown were excluded. Calculation of the number of leaves in Kailaan plant was conducted for every 3 days until the plants are 24 days old. The measurement of leaf area was carried out when the plant was 24 days after planting, where the selected leaves were in the position of seven strands from the bottom of the stem for all observation samples. Measurement of wet weight was conducted when the plant was 24 days old after planting. Measuring the amount of leaf chlorophyll was performed when the plant was 24 days old after planting. Measurements were conducted before the plants were removed from the planting media. Measurements were conducted by using Chlorophyll meter from Konica Minolta SPAD 502. The selected leaves were six strands from the bottom of the base which were carried out in all treatment samples. Measurements were only carried out on the center of the leaf because the middle part contains the most chlorophyll by avoiding measurements on the leaf bone and mesophyll tissue. The measurement of plant length was performed after the plants were 24 days old after planting. The plants were placed on a flat medium to measure the length of Kailaan by using a ruler in a row, starting from the root to the top of the Kailaan stem. Stomata observation was conducted by using a digital microscope. The observation method for diameter of leaf stomata opening was conducted by selecting one of the three samples in each treatment, and laterby applying transparent nail polish to the middle at the top and bottom of the leaves. In addition, after drying, transparent nail paint was released from the leaves and observed by using a digital microscope of 40x magnification. Statistical analysis was conducted to test the significance of treatment in this study. Data from the study using two treatments i.e. different frequency levels and duration of time of exposure to sound in plants were analyzed using analysis of variance (ANOVA). After the ANOVA test was carried out and it was found that the results were significantly different then it was further tested using DMRT (Duncan's Multiple Range Test) (Kamal et al., 2018; Hossain et al., 2019).

RESULTS AND DISCUSSIONS

The results of Kailaan products after undertaking several treatment variations are depicted in Figure 3 and Figure 4. From the visual observations, Kailaan treated with PAFT demonstrated better result than the untreated Kailaan plants. Meanwhile, the quality of Kailaan plants among treatments was rather difficult to distinguish; thus, it was necessary to accurately measure vegetative parameters. Suwardi (2010) had also proven that there were significant differences between plants with PAFT and without PAFT. The results indicated that PAFT provided more optimal results in plant growth (Mishra et al., 2016; Chowdhury et al., 2014). Pujiwati et al. (2018) also explained the results of the research in which PAFT treatment on optimal frequency could improve the quality of vegetable crops including stomata openings, plant weight, harvest index, and leaf area with significant results.

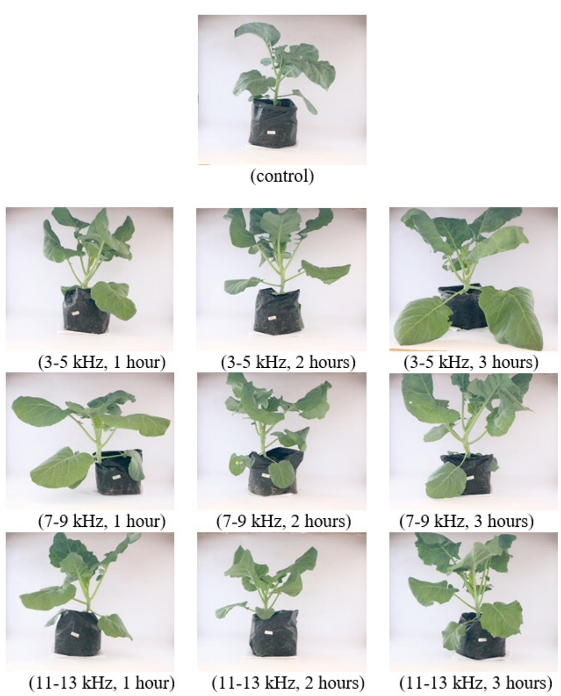

Figure 3. The results of Kailaan plant appearing side-by-side

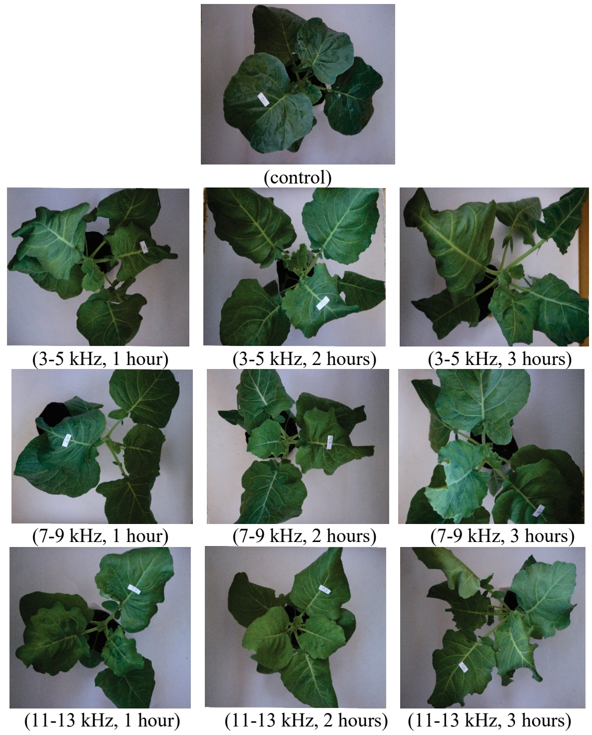

Figure 4. The results of Kailaan plant appearing above

From the data observed by the amount of leaf chlorophyll, it is apparent that the highest average value (80.86 cci) was found in the treatment frequency of 3-5 kHz and PAFT exposure time for 3 hours. Whereas, the lowest observation in the amount of leaf chlorophyll (48.96 cci) was found in the treatment frequency of 3-5 kHz and PAFT exposure time for 1 hour. The graph depicting the observation of the average number of chlorophyll leaves in each treatment is presented in Figure 5. The result of the PAFT test was able to increase the average of leaf chlorophyll by 61.5% than control treatment. From the ANOVA test results obtained that the treatment with the level of frequency and duration of exposure did not have a significant effect on the level of significance ($\alpha = 0.05$). However, PAFT in several studies has demonstrated to significantly increase the amount of leaf chlorophyll during growth. In several previous studies, it was proven that tomato, lettuce, and spinach plants which were given the PAFT treatment, significantly increased the amount of chlorophyll at a frequency of 0.08 ~ 2 kHz with an exposure time of 180 minutes compared to plants that did not apply PAFT (Hou & Mooneyham, 1999a; Hou & Mooneyham, 1999b). Whereas, the cucumber and sweet pepper plants are recognized to have the highest increase in the amount of chlorophyll at a frequency of 0.08 ~ 2 kHz with an exposure time of 180 minutes which is given once every day (Hassanien et al., 2014). Meng et al. (2012) in his research on the implementation of PAFT on strawberry

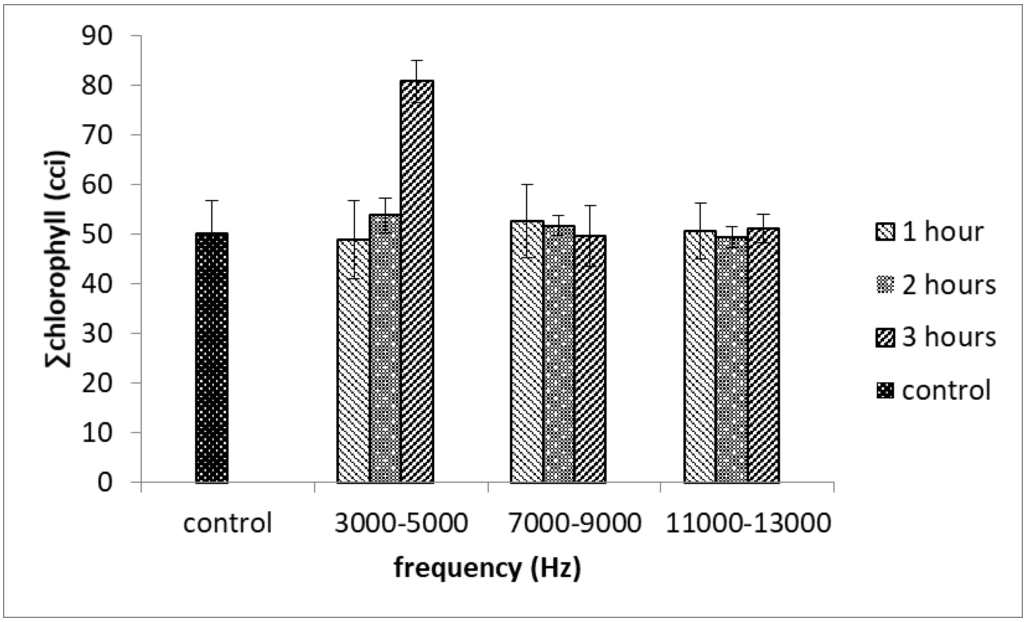

Figure 5. Relationship between variation in frequency and PAFT exposure time to the amount of chlorophyll of Kailaan leaves

plants, found that acoustic frequency treatments could optimally improve photosynthetic processes, which also affected the increase in the amount of leaf chlorophyll. Zakariya et al. (2017) tested PAFT on Mustard Pakcoy plants with significant results to increase total chlorophyll reaching 27.7%.

On the observation of Kailaan plant length, it is apparent that the highest average value (47.33 cm) was found in the treatment frequency of 3-5 kHz and the exposure time of PAFT for 3 hours. Meanwhile, the result from observations of the lowest plant length (30.00 cm) is found in the treatment frequency of 11-13 kHz and PAFT exposure time for 1 hour. Graphs of plant length observations are depicted in Figure 6. The result of PAFT test was able to increase the plant length by 35.2% than control plant. The statistical tests were conducted by using the real level ($\alpha = 0.05$) demonstrating that the treatment with various frequency and exposure time of PAFT, significantly affected the length of the Kailaan plant. From the results of Duncan's multiple range test (DMRT) with 5% level, it was found that various frequency treatment with the most significant effect was at 3-5 kHz with an average plant length of 40.00 cm, while the treatment with PAFT exposure time for 3 hours, an average plant length was 43.33 cm. From this result, it is assumed that PAFT can have a significant effect on the length of the Kailaan plant, where the best treatment for plant length is reached at a frequency of 3-5 kHz and exposure time of 3 hours. PAFT is proven to significantly increase plant length. Wang et al. (2003) proved the success of PAFT in significantly increasing plant length in paddy rice seeds, compared to the untreated

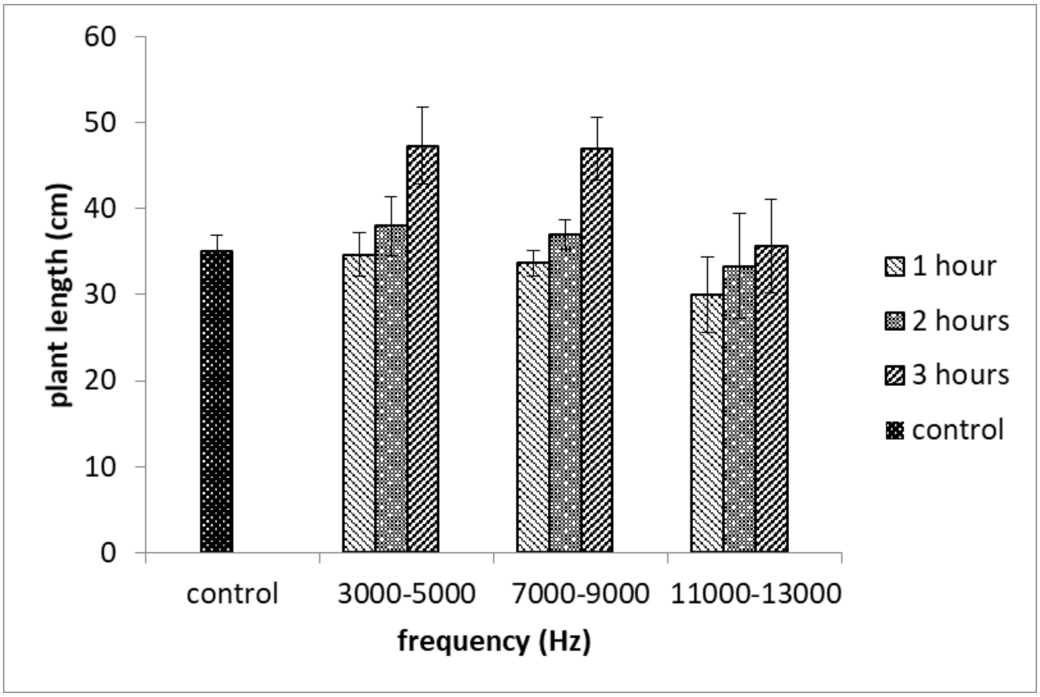

Figure 6. Relationship between variations in frequency and PAFT exposure time to Kailaan plant length

paddy rice seeds. In this study, the best results were obtained at the acoustical instrument frequency of 0.4 kHz. Cai et al. (2014) proved that PAFT could significantly increase the length of vegetable plants with the best frequency treatment at ±2.5 kHz.

The results Kailaan plant wet weight indicated that the highest value of plant wet weight (84.00 g) was found in the treatment frequency of 3-5 kHz and the exposure time of PAFT for 3 hours. The lowest value of plant wet weight (34.66 g) was found in the treatment frequency 11-13 kHz and PAFT exposure time for 2 hours. Figure 7 illustrates the results of the average wet weight in each treatment. The result of PAFT test was able to increase the wet weight by 106.7% than control treatment. The results of the statistical analysis indicated that the treatment with variations in frequency and exposure time of PAFT significantly affected the wet weight of Kailaan plant. The results of DMRT demonstrated that the most significant frequency variation treatment was at a frequency of 3-5 kHz with an average wet plant weight of 64.33 g, while the treatment of PAFT exposure time with the most significant effect was at 3 hours with an average wet plant weight of 64.66 g. From the results of this statistical test, it is concluded that PAFT has a significant effect on Kailaan wet weight with the best treatment at a frequency of 3-5 kHz and PAFT exposure time for 3 hours. In several other studies, it was also proven that PAFT can significantly increase plant weight (dry weight and fresh weight). The 5 kHz frequency can increase the dry weight of wheat plants (Weinberger & Measures, 1979), while the 0.4 kHz frequency

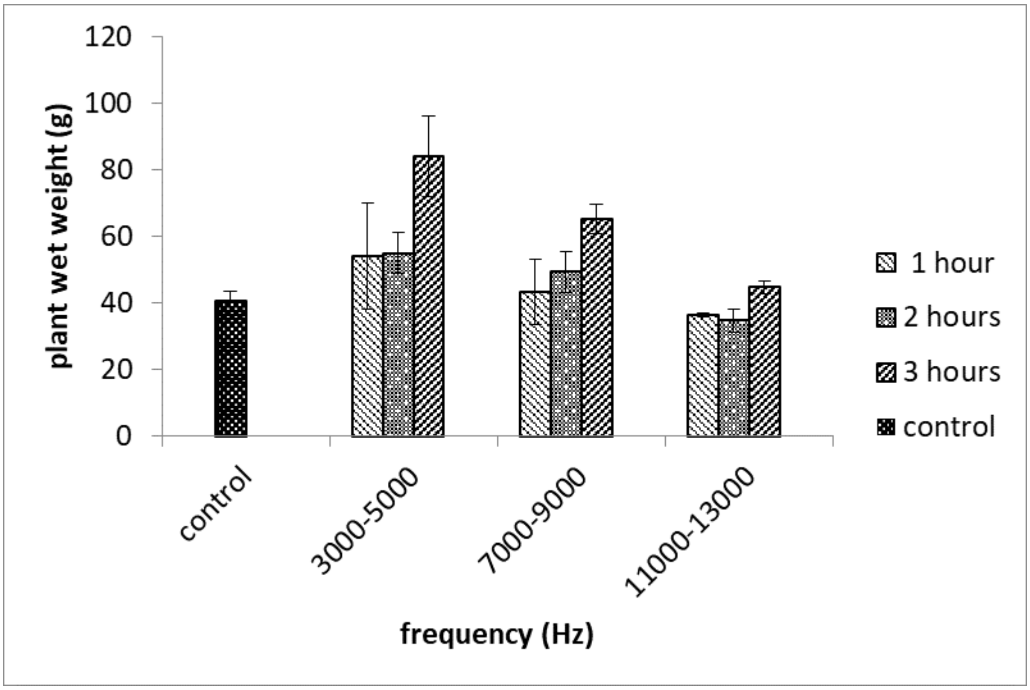

Figure 7. Relationship between variations in frequency and PAFT exposure time to Kailaan plant wet weight

can increase fresh weight on paddy rice seeds (Wang et al., 2003). Pujiwati and Djuhari (2014) also had proven that PAFT treatment with high-frequency could significantly increase fresh-weight of soybean plants. This result is also in accordance with the results of research conducted by Zakariya et al. (2017) with PAFT at a frequency of ± 2 kHZ increasing the wet weight of vegetable plants by 25.6%. Cai et al. (2014) also examined the utilization of PAFT which could significantly increase the wet weight of vegetable plants with the best frequency treatment on ±2.5 kHz.

The next parameter measured to observe Kailaan leaf area, in which the highest leaf area average value (207.06 cm^2) was found in the treatment frequency of 3-5 kHz and PAFT exposure time for 3 hours. The lowest leaf area (98.58 cm^2) was found in the treatement frequency of 11-13 kHz and PAFT exposure time for 2 hours. Figure 8 presents observations of leaf area for each treatment. The result showed that PAFT was able to increase the leaf area by 71.0% than control plant. The statistical analysis test indicated that the treatment with variations in frequency and exposure time of PAFT had a significant effect on Kailaan leave area. This finding is evidenced, where the treatment with frequency variations has sig. ($\alpha = 0.002$) and treatment with variations in PAFT has sig. ($\alpha = 0.00$), indicating that both treatments have < ($\alpha = 0.05$). Therefore, ANOVA test was conducted by using DMRT for both treatments. The result of DMRT advanced test with a real level of 5% indicated that the most significant frequency variation treatment was at a frequency of 7-9 kHz with

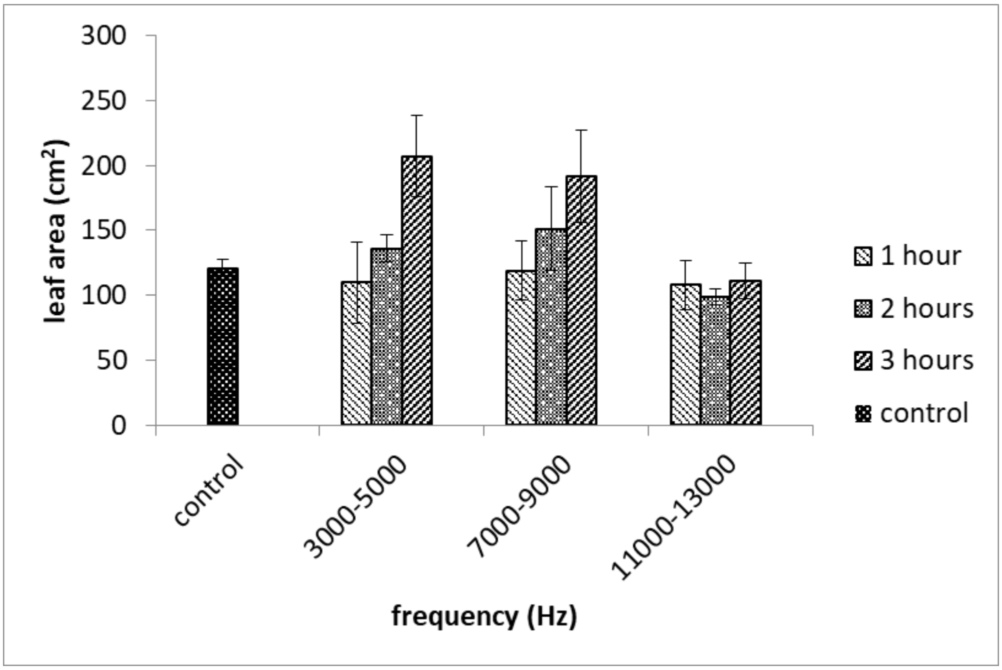

Figure 8. Relationship between variation in frequency and PAFT exposure time to Kailaan leaf area

an average leaf area of 153.92 cm^2, while the treatment with PAFT exposure time was the most significant at 3 hours with a leaf area average of 169.80 cm^2. From these results, it is assumed that the utilization of PAFT can have a significant effect on the area of Kailaan leaves where the best treatment is at a frequency of 7-9 kHz and the length of time exposed is 3 hours. The increase in leaf area due to PAFT treatment is also in line with the results of research conducted by Pujiwati and Djuhari (2014) where PAFT treatment with high frequency (± 10 kHz) could significantly increase the leaf area of soybean plants. This result is also in accordance with the study of Zakariya et al. (2017) who utilized PAFT for Pakcoy vegetable plants, presenting a significant increase in leaf area to reach 30.9%.

Observation of the height of the Kailaan plant has also been carried out, indicating that the highest average value (11.60 cm) was found in the treatment frequency of 3-5 kHz and PAFT exposure time for 2 hours. The lowest plant height (7.33 cm) was found in the frequency treatment 11-13 kHz and PAFT exposure time for 1 hour. Figure 9 provides observations of plant height for each treatment frequency and exposure time of PAFT. It shows that PAFT treatment was able to increase the plant height by 0.8% than control treatment. The results of the statistical analysis test indicated that the frequency variation treatment had a significant effect on the height of the Kailaan plant. The frequency treatment parameter has sig $(A = 0.005) < (\alpha = 0.05)$. In DMRT test, it is concluded that the most significant frequency variation treatment was at a frequency of 3-5 kHz with an average

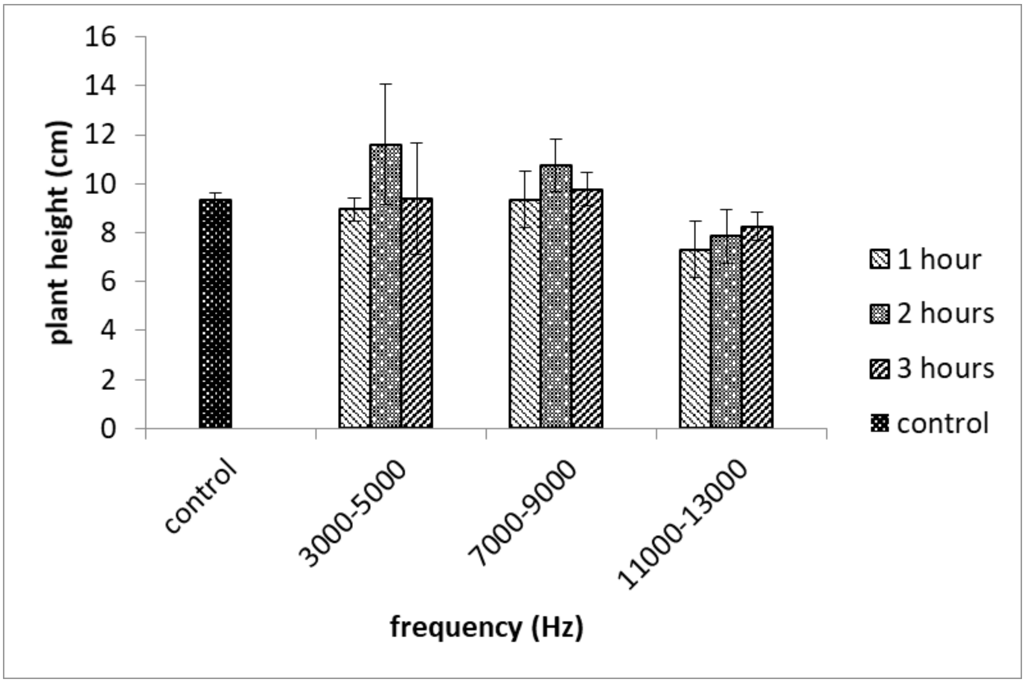

Figure 9. Relationship between variation in frequency and PAFT exposure time to Kailaan plant height

plant height of 9.98 cm. In a study conducted by Carlson (2013), it was proven that PAFT was able to increase plant height by using a 3-5 kHz frequency treatment given once a day for 180 minutes. In the study of Pujiwati and Djuhari (2014) high-frequency PAFT gave significant results to increase plant height. Whereas, in the study of Zakariya et al. (2017), it was proven that PAFT was able to increase vegetable height significantly until it reached 10.4%.

From the data observed, the number of Kailaan leaves with the highest average value was found in the treatment frequency of 3-5 kHz and 11-13 kHz with the exposure time of PAFT for 3 hours with 11 strands. Meanwhile, the smallest number of leaves was found at the 11-13 kHz frequency and PAFT exposure time for 1 hour with 9.33 strands. The results of observations on the number of leaves in each treatment are depicted in Figure 10. It shows that PAFT was able to increase the number of leaves by 13.9% than control plant. The results of the statistical analysis indicated that the exposure to PAFT significantly affected the number of leaves of the Kailaan plant. The time of exposure had sig. (A = 0.032) < (α = 0.05). From the results of DMRT follow-up test with a real level of 5%, it was found that the best result of the treatment for PAFT exposure time was at 3 hours of treatment with 10.88 leaves. In a study conducted by Carlson (2013) and Hou et al. (1999a), it was proven that PAFT was able to increase the number of leaf plants by applying a 3-5 kHz frequency treatment given once a day for 180 minutes.

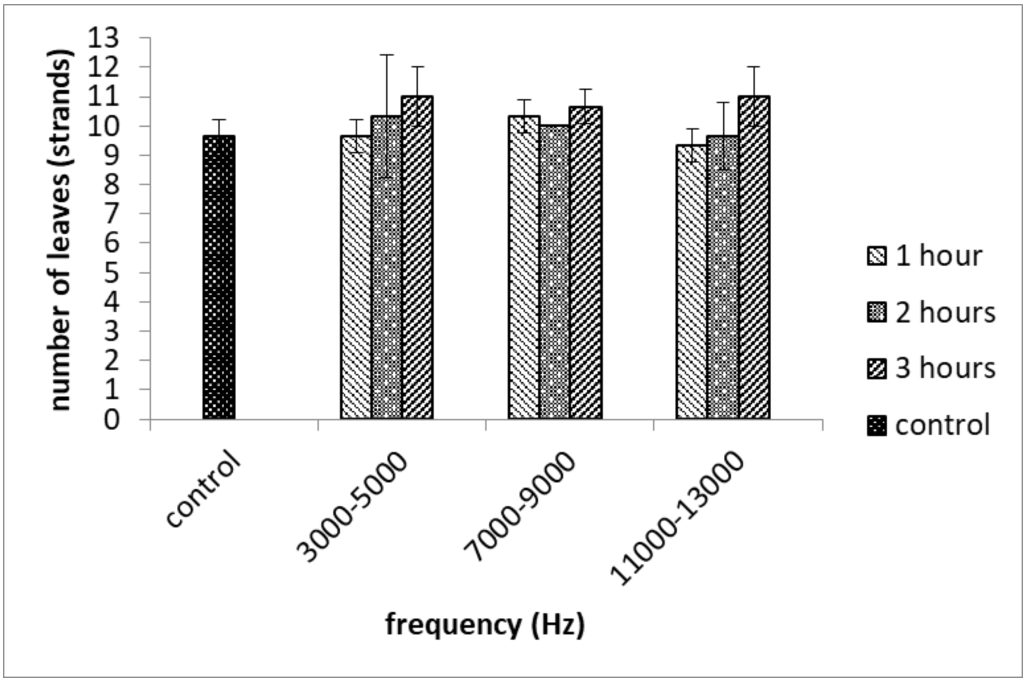

Figure 10. Relationship between variations in frequency and PAFT exposure time to number of Kailaan leaves

Stomata is the most important part of the plant due to its function as a place of respiration process. PAFT is a technology that utilizes the frequency of sound to stimulate the wider opening of leaf stomata. In Figure 11 and Figure 12, stomata openings are given PAFT exposure at frequencies of 3-5 kHz, 7-9 kHz, and 11-13 kHz as well as exposure times of 1 hour, 2 hours and 3 hours. From Figure 11 and Figure 12, it can be concluded that the total distribution of the widest stomata opening is in the lower stomata of the leaf. In addition, wider stomata openings are in the PAFT treatment with a frequency of 3-5 kHz compared to the treatment of 7-9 kHz, 11-13 kHz and control, where the PAFT treatment affects both stomata opening at the bottom and top of the leaf. At the best treatment, which is at a frequency of 3-5 kHz and exposure time of 3 hours, the most optimal stomata opening diameter at the top of the leaf was 89.19 - 93.45 μm and the stomata opening diameter at the bottom of the leaf was 136.69 - 140.74 μm. Thus, PAFT with a frequency scale and optimal exposure time can have a significant effect on the stomata openings of Kailaan plant. PAFT was able to increase the stomata opening at the top part of the leaf by 30.5%, and increase the stomata opening at the bottom part of the leaf by 79.4% than control treatment. Carlson (2013) had proven that frequency of 3-5 kHz had an effect on the optimal opening of the stomata to grasp free nutrients in the air including nitrogen and water. Pudjiwati and Djuhari (2014) suggested in a study that PAFT with high sound frequencies influenced stomata openings which ultimately increased the uptake of free nutrients in the air increasing plant productivity. This result is also in line with the study of

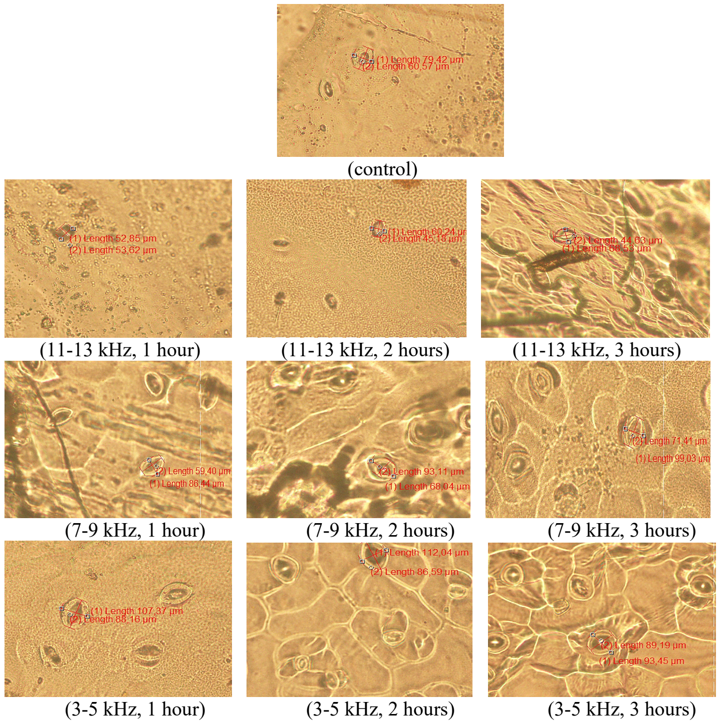

Figure 11. Enlargement image of stomata opening at the top part of the leaf

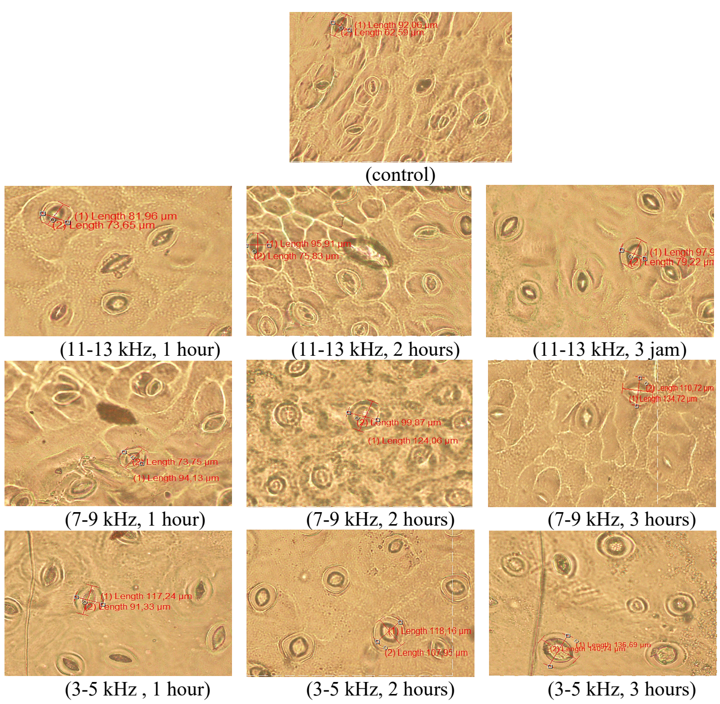

Figure 12. Enlargement image of stomata opening at the bottom part of the leaf

Zakariya et al. (2017) who applied PAFT to Mustard Pakcoy plants, in which leaf stomata openings increased to 28.4%.

CONCLUSIONS

Based on the results of the study, it can be concluded that the frequency of 3-5 kHz and exposure time of 3 hours are the best plant acoustic frequency technology (PAFT) treatment in Kailaan with the value of leaf chlorophyll, plant length, wet weight, leaf area, plant height, number of leaves, stomata opening width at the top of the leaf, and stomata opening width at the bottom of the leaf are 80.86 cci, 47.33 cm, 84.00 g, 207.06 cm^2, 11.60 cm, 11 strands, 89.19 ~ 93.45 µm, and 136.69 ~ 140.74 µm, respectively. The result of the PAFT test was able to increase the average of leaf chlorophyll by 61.5%, increase the plant length by 35.2%, increase the wet weight by 106.7%, increase the leaf area by 71.0%, increase the plant height by 0.8%, increase the number of leaves by 13.9%, increase the stomata opening at the top part of the leaf by 30.5%, and increase the stomata opening at the bottom part of the leaf by 79.4% than control treatment. It was found that the PAFT had a significant effect on the productivity and quality of Kailaan plants. For further development, PAFT using gamelan music can be combined with plant response-based sensing to improve the quality of vegetables in a closed bioproduction system.

ACKNOWLEDGEMENTS

The authors wish to acknowledge support from Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Brawijaya, for assistance given during the research. This study was funded by Associate Professor Research Grant Program (Hibah Doktor Lektor Kepala 2019), University of Brawijaya, the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia.

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