Increasing the Productivity of Rice (*Oryza sativa*) Crop via Exposure of a Micro Chip Audio Generator System

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***Abstract* – A technology revolution is needed to overcome the problem of food self-sufficiency in agriculture, i.e. a smart chip audio organic growth system (SC-AOGS). The objective here is to design, produce, and apply the SC-AOGS to rice (*Oryza sativa*) crops. The SC-AOGS exposes audio sound of local insects to the crops and triggers the opening of stomata so that the plants are able to absorb sunlight. The results show that better yields of crops under SC-AOGS exposure are obtained, the best yields are obtained at 4000 Hz, and the location of the beds does not affect the yields.**

***Keywords* – *SC - AOGS*, rice crops, frequency variation.**

1. Introduction

The Agricultural Development Master Plan of 2015-2045 states the sustainable bio-industry agriculture as one of the main options for agricultural development in the future.

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The main innovation (technology) supporting the development of bioindustry agriculture is via the approach of bioscience [1], bioengineering [2], and other frontier technologies. Agricultural Research and Development Agency, i.e. Balitbangtan, has a very important and strategic role in generating agricultural innovation to encourage the achievement acceleration of strategic targets of the national agricultural development programs. In addition, in line with the increasing complexity of the challenges facing agricultural development in the future, both in the aspects of production and the economy, as well as resources and environment, future agricultural system reorientation is demanded, which of course is also considering superior and quality agricultural innovations. In carrying this heavy task, Balitbangtan cannot work alone, hence strategic agricultural research, assessment, and strategic development (KP4S) is needed although it has to accommodate the diversity among partners.

It is expected that through this KP4S, cooperation programs become more effective and efficient in increasing the number and quality of invention and innovation of agricultural research and development results especially in supporting the development of agriculture.

A solution to the above problems, especially in the applied research with bioengineering approach, Smart Chips Audio Organic Growth System (SC-AOGS) is produced, which has cybernetic, holistic, and effective characteristics to improve agricultural productivity. The developed SC-AOGS is an advanced technology in the field of Acoustic as an invention of ready-to-use technology in agriculture for enhancing food security [3] and utilizing a modification of audio spectrum from local insects combined with foliar fertilization [4], [5]. Exposing sound waves with frequency of 3000 Hz - 6000 Hz toward agricultural plants may stimulate the opening of stomata [6], [7]. The term "smart chip" refers to the ability of the device in displaying measurements that provide information concerning the control time, and in the future, may provide information on humidity, temperature, and light intensity, which is connected to a computer system for data analysis and also accessible using android system.

Optimization of audio variables for this device may be conducted, namely frequency and intensity variables to produce plants that are able to absorb nutrients and solar energy optimally so that the resulting crops have an impact on increasing the productivity and quality of the plants [8]. SC-AOGS is applied when photosynthesis takes place. Other biological processes that play an important role in photosynthesis are transport of carbohydrates, protein formation, ion balance control, regulation of plant stomata, and water use activation of plant enzymes [9], [10], [11]. The use of SC-AOGS resulted in plants consuming nutrients by air that contain various substances that are needed by the plants. The highest yield is obtained on an inorganic treatment due to the high availability of nutrients at the time of leaf fertilization. The lowest yield is caused by a shortage of plant supply in nitrogen resulting in a reduction in crop productivity [12], [13], [14]. The SC-AOGS device designed in this study is made to be more compatible and comprehensive. The size of this device is small but has a maximum audio power output so that it may reach a wide area and is easy to move around. The SC-AOGS has been tested in the laboratory and applied in the field with 50% -100% increase yield for varieties of crops in several places, namely: (1) potato and peanut plants in Dieng Plateau, (2) red rice in Bantul, (3) chili plant in Bantul, and (4) corn plant in Ponorogo.

The SC-AOGS which is developed through laboratory and field test procedures has unique and novel specifications as it uses basic sounds of native Indonesian local insects that are currently going extinct on agricultural land. After modifications using Sound Forge acoustic technique, the device is then developed further in the form of microchip so that it becomes simpler. Moreover, the production price becomes cheaper because of the selection of more intelligent components.

2. Experimental

The study began in March 2017 in order to prepare the SC-AOGS device and conditioning the farmers. Meanwhile, rice cultivation activities are conducted from the months of August to November 2017. The research sites are (i) farmland of Kalasan farmer group, Selomartani, Soman, Sleman Regency of Yogyakarta, and (ii) histology laboratory of Anatomy Microscopy Department of Biology Education, Mathematics and Natural Science, Universitas Negeri Yogyakarta. The object of this study is rice plant (*Oryza sativa*), farming area used in this research is 100 m^2 for the treatment plants (given the sound exposure) and 100 m^2 of control plants (which are not given sound exposure). The variables used in the study are (i) independent variable, which is the sound frequency used for exposing the rice plants, (ii) control variable, that is the sound exposure time starting from 07.00 to 09.00 AM, and (iii) dependent variables, viz. height and number of stems of the rice plants, and the productivity of the rice crops.

The procedures in this study can be explained as follows. (1) Preparing the tools used in this study, i.e. SC-AOGS device and a table as the SC-AOGS stand, (2) exposing sound using the SC-AOGS device at peak frequencies (in Hz) of 3500, 4000, and 4500 (see Figure 1.). Sound exposure is done every day for 13 weeks. For the control plants, the same procedure is given, although this group is not given sound treatment.

Data collection in the rice field can be explained as follows. The measurement of plant height is conducted during the rice planting at the ages of 1 and 3 weeks. The measurement of the number of plant stems is done in a single clump of rice plant during the rice planting at the ages of 1 and 3 weeks. The measurements of the plant height and number of stems are performed on all plant groups treated and not treated using the SC-AOGS. The measurement of rice crop productivity is done by collecting all the rice yields in the form of rice grains. The measurement data are then entered into the data tabulation. Microsoft Excel 2017 and Origin Pro 8.0 are used to analyze the data obtained from the results of the treatment and control of the plants.

Figure 1. The SC-AOGS is mounted on a table facing towards the rice plants ready to be used (left), whereas the farmers are given some instructions concerning the use of the SC-AOGS (right)

The procedures in planting the rice plants may be given as follows. (1) Preparing the land, (2) land processing is done by making beds (land made plots). This is done by ploughing the land as deep as 40 cm - 50 cm, and then rested for 15 days. The beds have a width of 80 cm, height 30 cm, and a length following the available land, while the distance between beds is approximately 80 cm. (3) Foliar fertilization is done by spraying nutrients when SC-AOGS is operated. Conventional fertilization is still conducted to see the difference of the results both in the treatment and control plants.

3. Results and Discussions

The objectives that have been realized through this research activity are (1) designing and producing the SC-AOGS device that has special specifications that can be mass marketed, and (2) applying the SC-AOGS device to improve rice productivity which can be seen from the morphology and productivity aspects. In general, the SC-AOGS device consists of (1) an MP3 sound module unit, (2) a sound amplifier unit to amplify the sound signal, and (3) a power supply unit via an accumulator, battery, or solar cell. Sound output occurs in the loudspeaker or horn. This can be seen in the diagram block in the left of Figure 2. The SC- AOGS electronic circuit (chip) can be observed in Figure 2. (right).

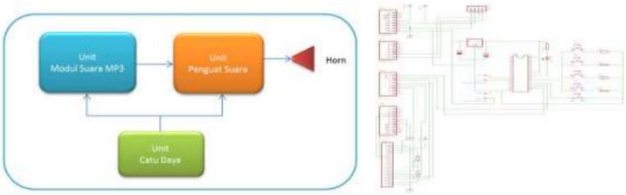

Figure 2. The diagram block of the SC-AOGS (left) and the electric circuit (chip) of the SC-AOGS

In order to make sure that the device is working properly, validation and stability tests of the output peak frequencies of the SC-AOGS are conducted. The results of the tests may be observed in Table 1. In general, the results show that the peak frequencies of (in Hz) 3000, 3500, 4000, 4500, and even 5000 are relatively stable without any significant change. As may be observed in Table 1., difference distances of peak frequency measurements do not alter the peak frequency that much. Except for the theoretical peak frequency of 5000 Hz, the measured peak frequency is different more than 300 Hz (compared to the average output peak frequency). The differences of the output peak frequencies may be caused by the constant changing of the environmental factors, such as wind direction and speed, humidity, and temperature [8]. The output sound intensity level from the SC-AOGS device is in the range of 0 – 100 dB. An example of the output signal on a computer screen corresponding to a certain peak frequency may be observed in Figure 3.

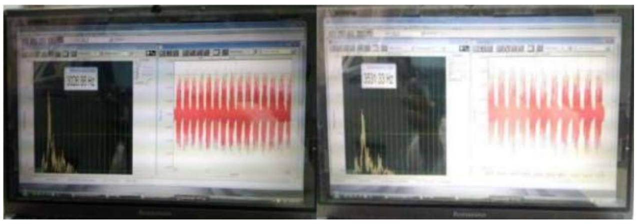

Figure 3. Examples of signal output obtained from the SC-AOGS with certain peak frequencies

Table 1. Comparison of the theoretical and measured (output) peak frequencies of the SC-AOGS

Theoretical	Output peak frequency (Hz)							
peak frequency	2.5 m	5.0 m	7.5 m	10.0 m	12.5 m	15.0 m	average	deviation
3000 Hz	3143.5	3099.61	3120.12	3164.06	3184.57	3017.58	3121.57	121.573
3500 Hz	3503.9	3509.77	3609.38	3609.38	3562.5	3500.98	3549.32	49.3183
4000 Hz	4110.3	4040.04	4072.2	4004.88	4019.53	4163.09	4068.34	68.34
4500 Hz	4502.9	4508.79	4505.86	4599.61	4517.58	4511.72	4524.41	24.41
5000 Hz	5373.1	5364.26	5375.98	5393.55	5381.89	5311.52	5366.72	366.717

The plant height measurement results as one of the growth indicators in all treatments can be seen in Figure 4. The measurement is taken in the first and third weeks on all treatments (with and without sound exposure). In general, the plant heights in the first and third weeks are higher for the treatment plants at all three frequencies compared to the control group [5]. The control group shows the same heights in all the weeks the measurement is taken (the height is higher in the third week compared to the first week). Plant heights in the first and third weeks show differences between the treatment and control groups. The treatment group shows a higher plant height compared to the control plants. The plant height of the control group in the first week is 27.68 cm, while the treatment group is 31.2 cm, 34.54 cm, and 27.68 cm at 3500 Hz, 4000 Hz, and 4500 Hz, respectively. In the third week, the plant height of the control group increases to 39.99 cm, whereas the plant height of the treatment group increases as well to 58.66 cm, 59.55 cm, and 44.25 cm for 3500 Hz, 4000 Hz, and 4500 Hz, respectively. The highest increase in the plant height is obtained for treatment plants with sound exposure of 4000 Hz. The lowest increase of the plant height for the treatment group is obtained with sound exposure of 4500 Hz.

The number of plant stems measurement in each clump as an indicator of growth [8] is shown in the bottom of Figure 4. The number of stems is higher in the treatment group for all three frequencies compared to the control group, both in the first and third weeks. The number of stems in the first and third weeks shows differences between the treatment and control groups. The number of stems for the control group in the first week is 4 stems, while the treatment group is 8.44 stems, 10.44 stems, and 10.46 stems at 3500 Hz, 4000 Hz, and 4500 Hz, respectively. The number of stems in the third week is 10.44 stems for the control group, whereas it is 26.22 stems, 28.96 stems, and 12.26 stems for sound exposure with frequencies of 3500 Hz, 4000 Hz, and 4500 Hz, respectively. The highest increase of the treatment plant is again obtained with sound exposure of 4000 Hz, and the lowest increase is obtained for 4500 Hz.

The total productivity measurement of the rice crops is done when the plants are 13 weeks old. This may be observed in Figure 5. Figure 5. shows that the productivity given by the harvest weight of the treatment plants is greater than the control plants. The productivity of the control plants is 150 kg, whereas the productivity of the treatment plants are 199 kg, 338 kg, and 187 kg for sound exposure of 3500 Hz, 4000 Hz, and 4500 Hz, respectively.

This means that there is an increase harvest (yield) of about 49 kg, 188 kg (100% increase), and 37 kg for sound exposure of 3500 Hz, 4000 Hz, and 4500 Hz, compared to the control plants. Figure 5. also clearly shows the highest increase of the productivity is obtained for sound exposure of 4000 Hz and the lowest increase is obtained for the frequency of 4500 Hz.

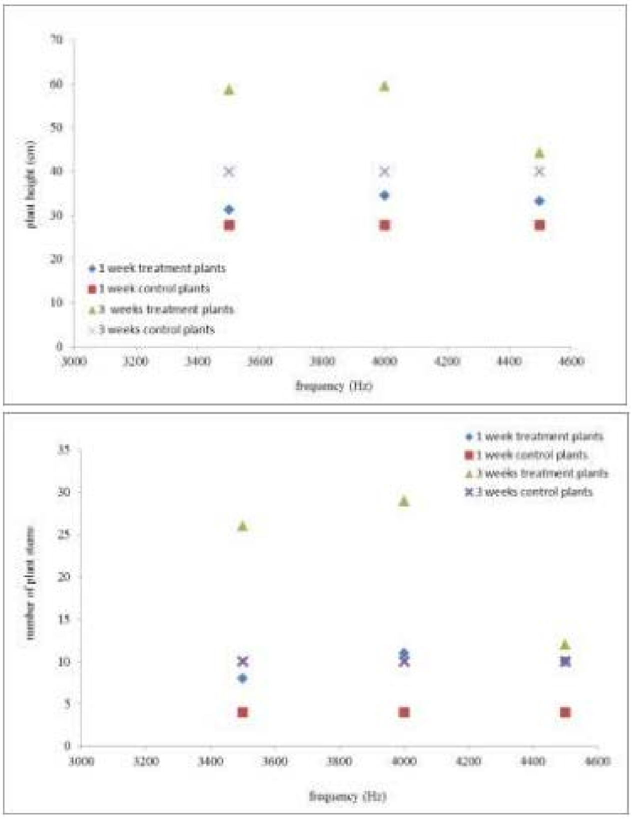

Figure 4. The measurement results of plant heights (top graph) and number of plant stems (bottom graph) of the rice crops on the first and third weeks with and without (control) SC-AOGS

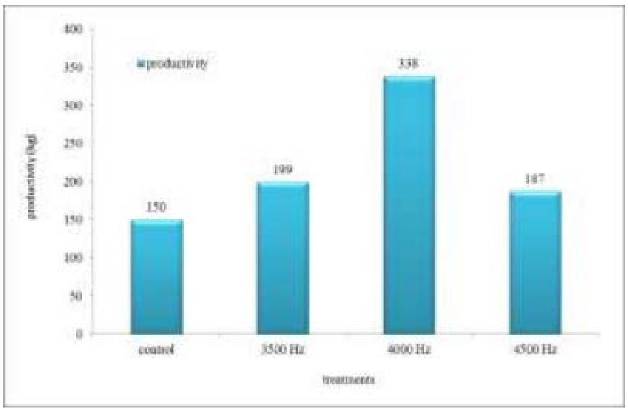

Figure 5. Productivity results of the rice crops with and without (control) SC-AOGS treatments

Location of the beds taken from a distance of 10 meters from the SC-AOGS device is also studied based on the productivity. This is given in Figure 6. Figure 6. show that the average productivity of rice crops with sound exposure of 3500 Hz, 4000 Hz, and 4500 Hz is about 3-7 kg, 6-10 kg, and 2-8 kg, respectively.

Graph 7. shows that the average productivity of paddy crops at the frequency of 3500 Hz is about 3-7 kg. Based on the aforementioned results it may be concluded that the location of the beds does not affect the productivity of rice crops. Figure 6. also confirms that the highest productivity is obtained for the treatment plants given sound exposure of 4000 Hz based on all location of the beds. This is also true for the lowest increase of rice productivity, which is obtained for the treatment plants with sound exposure of 4500 Hz based on all location of the beds.

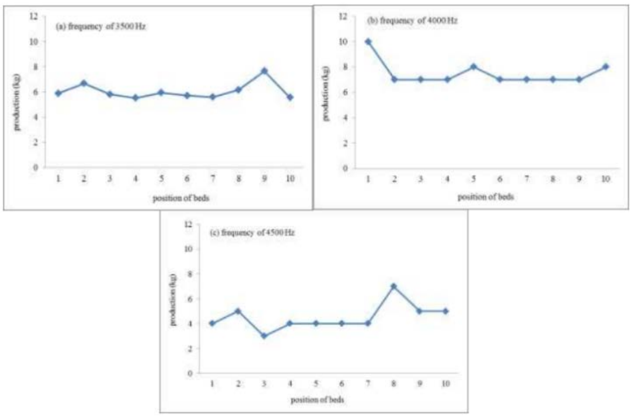

Figure 6. The productivity of the rice crops as observed from the position of the beds with SC-AOGS treatments of (a) 3500 Hz, (b) 4000 Hz, and (c) 4500 Hz.

4. Conclusions

The SC-AOGS has been designed and produced in this study. This is an agricultural acoustic wave technology combined with foliar fertilization with optimization of audio variables, such as intensity and frequency, to increase productivity and crop quality in line with efforts to increase food security. The SC-AOGS, which is implemented in the rice field, is small, practical, and also has a high capacity of sound exposure for large area. The SC-AOGS has been applied to improve the productivity of rice crops as observed from indicators of plant growth rate, i.e. plant height and number of stems in one clump, which is better than control group. From this research, it may be concluded that (1) the treatment plants are better than the control plants based on plant height, number of stems, and productivity, (2) the best productivity is obtained for the treatment plants with sound exposure of 4000 Hz with the total productivity reaching twice (100%) of that of the control plants, and (3) the location of the beds does not affect the productivity of the rice crops, which indicates that the intensity of the sound does not affect the productivity of the rice crops.

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