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by I Made Anom Sutrisna Wijaya
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LED (Light Emitting Diode) Light Provides Positive Effects on Growth and Productivity of *Pakcoy* Mustard (*Brassica Rapa* L.)

IMAS Wijaya, GT Sigmarawan and IPG Budisanjaya

Department of Agricultural Engineering, Faculty of Agricultural Technology, Udayana University, Badung, Bali

E-mail: anomsw@unud.ac.id

**Abstract.** Plant photosynthesis is strongly influenced by light, carbon dioxide, the availability of water and nutrients found in the soil. In this study, LED light combined with gamelan music *Gong Kebyar* was applied to *pakcoy* plants to see its effect on growth and productivity. The LED light that was applied is white, red-blue, and red-white-blue LED light, which is given for 20 hours from 06.00 to 02.00. Gamelan music *Gong Kebyar* is applied for 3 hours, from 06.00 to 12.00. Variables observed included plant height, canopy area, leaf greenery, root length, and plant biomass. The results showed that white LED light had a negative effect, while the red-blue LED, and red-white-blue light had a positive effect on the growth and productivity of *Pakcoy* mustard. The use of red-blue LED light combined with gamelan music *Gong Kebyar* gave the highest value on plant height (27.176 cm), canopy area (1457.59 cm²), leaf greenery (160.03), root length (23.6 cm), and plant biomass (5.05 g). It can be concluded that the use of red-blue LED light combined with gamelan music *Gong Kebyar* increases the growth and productivity of *pakcoy* mustard.

1. **Introduction**

The indoor cultivation system is a cultivation technique carried out in a room with controlled environmental conditions that can be adapted to the micro-climate of the plant. According to [12], indoor cultivation systems produce room temperatures that are not as hot as open spaces and can minimize pest disturbances, so that plants can grow optimally. In indoor cultivation systems, plants are not optimal in getting sunlight for photosynthesis. To overcome this, artificial light is used to manipulate sunlight. Artificial light used in cultivation must have the right quality so that plants can carry out photosynthesis optimally. In the process of photosynthesis, chlorophyll can absorb blue waves (400 - 500 nm) to red (600 - 700 nm) so that artificial light designed for plant growth must emit these waves [18]. LED light (light emitting diode) has a wavelength of 400 nm - 700 nm [1] and does not produce high temperatures so that it can be used to increase plant growth [14].

Many research on the utilisation of LED light in plants has been carried out [28] found that red LED lights had a positive impact on the growth of *chrysanthemum* plants. While, [27] found that combination of red-blue LED lights gave the best growth of *chrysanthemum* plants. According to [9] LED lights can speed up the harvest of lettuce, where blue LED lights can stimulate vegetative growth.
while red LEDs can speed up the flowering process [11] stated that the combination of red, white and blue LED lights for 16 hours produced many positive effects on the growth of lettuce. The use of white light is thought to produce a balanced amount of light spectrum so the photosynthesis processes is running better.

Besides light, other factors that can affect plant photosynthesis are carbon dioxide, water and nutrients. The optimal photosynthesis process will produce maximum plant growth. One of the technologies that have been developed to produce maximum growth in plants is by utilizing sound waves which is commonly called sonic blooms. Sonic bloom utilizes high frequency sound waves to stimulate the opening of stomata [15] so it accelerates the rate of absorption of carbon dioxide, water and minerals in the soil. Naturally, plants get sound sources from natural environments such as animal sounds and sounds that come from daily activities [4] examined the exposure of Balinese gamelan music on pakooy mustard with different musical nuances, and he was found that Balinese gamelan music with joyful nuances had a positive effect on the growth and productivity of pakooy mustard. Sonic Bloom also utilized by [20] to increase the productivity of pakooy mustard. They found that combination of sonic bloom and monochromatic light increased pakooy production by 40.08%.

Based on those studies, this research was conducted to determine the effect of gamelan music Gong Kebayar combined with LED light on the growth and productivity of pakooy mustard, and to determine the combination of gamelan music Gong Kebayar and LED light that gave the best growth and productivity to pakooy mustard. Pakooy mustard is selected as an object of this research because pakooy mustard responsive to environmental changes and high demand for consumption. The use of Balinese gamelan music Gong Kebayar is based on the study of [4] and each plant can respond and like different music [24].

2. Methodology

2.1. Tools and materials
The tools used in the study include growth chamber, analytic scales, oven, thermo-hygrometer, lux meter and meter level. The growth chamber is equipped with speakers with a frequency response of 280 Hz - 18 kHz, HPL (High Power LED) with 12-18 volt LED drivers 300mA ± 5%. Every 1 Watt HPL has a red HPL specification of 2.2 - 2.4 volts 350 mA, blue HPL 3 - 3.2 volts 350 mA, and white HPL 3.3 - 3.5 volts 350mA. In addition, the growth chamber is also equipped with exhaust and exhaust. The materials used in the study were P1 pakooy hybrid seedlings, fertile soil, compost, NPK fertilizer, and polybags diameter 25 cm.

2.2. Experimental design
This study used a factorial complete randomized design with 3 treatments and 1 control, so that 4 combinations were obtained. Each treatment was repeated 5 times. The experimental treatment were as follows:

P1: Combination of gamelan music Gong Kebayar and white LED light
P2: Combination of gamelan music Gong Kebayar and blue-red LED light
P3: Combination of gamelan music Gong Kebayar and blue-red-white LED light
K : Control (without treatment and cultivated at greenhouse conditions)

2.3. Implementation of Research
Experiment begins with the preparation of planting media, seed seeding, planting seeds, maintaining plants, giving treatment and observing and measuring parameters. The planting medium used was a mixture of fertile soil and compost with a weight ratio of 50: 50, which was added to the polybag. Seed seeding is done in 10 days using fertile soil planting media. After 10 days of sowing, the seeds are transferred to the planting media. The treatment of combination of gamelan music Gong Kebayar and LED light in the growth chamber was carried out 3 days after planting. The treatment is illustrated in figure 1. The music given to each treatment has same frequency and amplitude (18 KHz and 20 - 90
dB), and applied for 3 hours starting from 09.00 o’clock. The LED light was applied for 20 hours starting from 06.00 o’clock at light intensity of 2000-2500 lux. Observations and parameter measurements was carried out every week until harvest.

![Picture of Pakcoy mustard inside the growth chamber (side view).](image)

**Figure 1.** Picture of Pakcoy mustard inside the growth chamber (side view).

2.4. Research Parameters

The parameters observed in this research included:

1. Plant height, measured from the base of the stem to the highest leaf and repeated on three different leaves. Height measurements are carried out every week until harvest.

2. The area of the canopy, measured using the image estimation method using Matlab 2017a software. The image is taken perpendicular to the top using a camera [4]. Measuring the area of the canopy is done every week until the harvest.

3. The greenness of the leaves, measured by green intensity values on the green channel of the leaf image taken [4]. Measuring the greenness of leaves is done at harvest time.

4. The length of the root, measured using a ruler from the base of the root to the tip of the longest root and repeated at three different root tips and then averaged. Measurement of root length is carried out after harvest.

5. Wet weight, measured after harvest using analytical scales.

6. Biomass, measured after harvest by drying the plant oven at 105°C for 24 hours. The drying results are then weighed using analytical scales [8].

3. Results and Discussion

3.1. Effect of Combination of Gamelan Music Gong Kebyar and LED Light on the Height of Pakcoy Mustard

The results of analysis of variance showed that the combination treatment of gamelan music Gong Kebyar and LED light did not significantly affect the height of Pakcoy mustard at the age of 0 and 1 week after planting. However, at the age of 3, 4, and 5 weeks after planting, the combination treatment of gamelan music Gong Kebyar and LED light showed a significant effect on the height of pakcoy mustard. The change of height of the Pakcoy mustard in each treatment are illustrated in figure 2, and the Duncan test results on the height of the pakcoy mustard are tabulated in table 1.
Figure 2. Changes in pakcoy mustard plant height in each treatment.

Table 1. Average height of pakcoy mustard

| Plant age (Weeks after planting) | Control (without treatment and cultivated at greenhouse conditions) | Combination of gamelan music Gong Kebay and white LED light | Combination of gamelan music Gong Kebay and blue-red LED light | Combination of gamelan music Gong Kebay and blue-red-white LED light |
|---------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 0                               | 2.76a                                           | 2.76a                                           | 2.72a                                           | 2.74a                                           |
| 1                               | 6.162a                                          | 6.302a                                          | 6.502a                                          | 6.212a                                          |
| 2                               | 10.23a                                          | 10.014a                                         | 11.726b                                         | 11.428b                                         |
| 3                               | 15.958b                                         | 13.37a                                          | 16.434b                                         | 16.02b                                          |
| 4                               | 21.224b                                         | 17.906a                                         | 21.764b                                         | 21.282b                                         |
| 5                               | 26.66b                                          | 20.058a                                         | 27.176b                                         | 26.928b                                         |

Note: Different letters behind the numbers on the same line indicate significantly different at a level of 5%.

It can be seen from table 1 that at 5 weeks after planting, the combination of gamelan music Gong Kebay and white LED light inhibit the growth of plant height of 24.8% compared to the control. This is presumably because the intensity of the white light produced is not optimal for carrying out photosynthesis. According to [5] the light absorbed by plants for photosynthesis depends on the wavelength, intensity, and time of irradiation. The light intensity of the LEDs might be smaller than the controls, so that the growth of plants given white LED light becomes obstructed. Thus it can be stated that the treatment of the combination of gamelan music Gong Kebay and white LED light has a negative effect on the height of the pakcoy mustard.

It can be also seen from table 1 that the combination treatment of the gamelan music Gong Kebay and the blue-red LED light produced the highest value of pakcoy height. This is in accordance with the
results of the study by [4] that Balinese gamelan music gong kebyar has a positive effect on the high growth of pakcoy mustard. Beside of music, light availability is an important influence in the cultivation process. According to [25] the red light that applied to plants can affect the elongation of plant leaves which causes the leaves to become long and slender. The red light needs to be combined with blue light which is thought to have a role to inhibit the lengthening of plant organs.

The combination treatment of gamelan music gong kebyar and blue-red LED light increase the height by 1.9% compared to controls. This is presumably due to the combination of gong kebyar music and light blue-red LEDs can accelerate the process of plant photosynthesis. Gamelan music Gong kebyar can stimulate the opening of leaf stomata so that chlorophyll is more optimal in absorbing light. Carbon dioxide and nutrients used for photosynthesis. This is in accordance with the statement of [19] which states that music can widen the opening of leaf stomata thus accelerating the absorption of water and minerals and CO₂ for photosynthesis. According to [17] in the photosynthesis process of chlorophyll pigments a and b absorb more red and blue light. Thus it can be stated that the treatment to the plant by gamelan music gong kebyar and blue-red LED light has a positive effect on the height of the pakcoy mustard.

3.2. Effect of Combination of Gamelan Music Gong Kebyar and LED Light on Canopy Area of Pakcoy Mustard

Based on the results of analysis of variance, it was found that the combination treatment of gamelan music Gong kebyar and LED light had a significant effect on the canopy area of the pakcoy mustard, so Duncan's further test was performed to determine the difference in value between treatments. The Duncan test results on the canopy area of the pakcoy mustard are tabulated in table 2, while the difference in plant canopy area in each treatment can be seen visually in figure 3.

### Table 2. Average canopy area of pakcoy mustard plants in each treatment.

| Plant age (Weeks after planting) | Canopy Area (cm²) | Control (without treatment and cultivated at greenhouse conditions) | Combination of gamelan music Gong Kebyar and white LED light | Combination of gamelan music Gong Kebyar and blue-red LED light | Combination of gamelan music Gong Kebyar and blue-red-white LED light |
|----------------------------------|-------------------|---------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 0                               | 6.28±1.6          | 6.55±1.5                                                     | 6.56±1.5                                       | 6.69±1.5                                       |
| 1                                | 8.75±1.2          | 8.92±1.1                                                     | 9.21±1.4                                       | 9.56±1.7                                       |
| 2                                | 393.49±48         | 399.88±48                                                   | 396.19±48                                       | 403.59±48                                       |
| 3                                | 842.01±95         | 847.04±95                                                   | 841.05±95                                       | 853.59±95                                       |
| 4                                | 1104.35±19        | 1104.35±19                                                  | 1104.35±19                                      | 1104.35±19                                      |

Note: Different letters behind the numbers on the same line show significantly different values based on the Duncan test with a level of α 5%.

It can be seen from table 2 that at 5 weeks after planting, the canopy area resulted from the combination of gamelan music gong kebyar and blue-red LED light was not significantly different from the combination of gamelan music gong kebyar and blue-red-white LED light, but significantly different with the combination of gamelan music gong kebyar and white LED light and control. It can also be seen that the combination of Balinese gamelan music gong kebyar and blue-red LED light produced the highest area of plant canopy compared to other treatments. This is in accordance with [4] which stated that the administration of Gong Kebyar gamelan music had a positive effect on the canopy area of pakcoy mustard. According to [26] red and blue lights are good for plant growth in terms of number and width of leaves. But it is not in accordance with the statement of [11] that the application of blue-red-white LED light on lettuce plants produced a higher leaf area than the application of blue-red light. This is presumably because the ratio of the combination of light given is
not appropriate and the absorption of each plant to light is not the same. According to [7] each plant
species captures different light depending on genetic factors and its environment. So that it can be said
that blue-red light is better used in pakeoy mustard.

| Control (without treatment and cultivated at greenhouse conditions) |
| Combination of gamelan music Gong Kebyar and white LED light |
| Combination of gamelan music Gong Kebyar and blue-red LED light |
| Combination of gamelan music Gong Kebyar and blue-red-white LED light |

0 Week | 1 Week | 2 Week | 3 Week | 4 Week | 5 Week

**Figure 3.** Differences in the canopy of the pakeoy mustard plant in each treatment.

The combination of gamelan music Gong Kebyar and blue-red LED light increased the growth of
the canopy area of pakeoy mustard by 24.2% compared to controls. This is allegedly due to the
combination of gamelan music Gong Kebyar and the light blue-red LED accelerate the absorption
of light, carbon dioxide and nutrients so that the photosynthesis process takes place more optimally.
According to [13] that red and blue light produces more effective waves of light for photosynthesis.
This was confirmed by the statement of [10] that red and blue light is the most effective light for
photosynthesis because leaves absorb more than 90% of that light. Thus it can be stated that the
treatment of the gamelan music Gong Kebyar and blue-red LED light has a positive effect on the
canopy area of the pakeoy mustard.

The combination of gong kebyar music and white LED light showed a significantly different value
to other treatments, with the smallest value of plant canopies. The combination of gong kebyar and
white LED light show the inhibition of growth of the canopy area of pakeoy mustard up to 53.4%
compared to controls. Pakeoy mustard that treated by a combination of gamelan music Gong Kebyar
and white LED light produce a smaller area and number of leaves compared to other treatments, as
seen in figure 3. This is presumably because the white light is not optimal for photosynthesis
compared to light blue-red and blue-red-white. It can be assumed that photosynthesis will be optimal if
plants get the right light so that the process of absorption of light by chlorophyll will be optimal. If
combined with the music, it can stimulate the opening of leaf stomata. So, it can be said that the
treatment of the combination of gamelan Gong Kebyar and white LED light has a negative effect on
the canopy area of the pakeoy mustard.
3.3. Effect of Combination of Gamelan Music Gong Kebyar and LED Light on the Greenness of Pakcoy Mustard Leaves

The results of analysis of variance showed that the combination treatment of gong kebyar music and LED light had a significant effect on the greenness of the pakcoy leaves. The greenness value of each treatment is presented in figure 4 and the Duncan test results are tabulated in table 3.

![Figure 4. The intensity of green pakcoy mustard leaves in each treatment.](image)

The results of Duncan test indicated that the intensity of the green color in the image of the pakcoy mustard shows a significantly different value in each treatment. The combination of gamelan music gong kebyar and blue-red LED light resulted the highest green color intensity which is laso indicated by dark green color of the pakcoy leaves. This is in accordance with the opinion of [21] that the exposure of gamelan music provides the highest leaf green index compared to other treatments. According to [4] gamelan music gong kebyar produces the highest leaf greenness value of pakcoy. According to [22] the red and blue LED lights give positive results to the anthocyanin and chlorophyll content of plants. The combination of gamelan music Gong Kebyar and blue-red LED light can increase the greenness of the leaves of the pakcoy mustard plant by 7.8% compared to the control.

| Treatment | Greenness (cm) | Root length (cm) | Wet weight (g) | Dry weight (g) |
|-----------|----------------|------------------|----------------|---------------|
| K         | 173.55b        | 17.46b           | 55.51b         | 2.93b         |
| P1        | 160.03a        | 12.40a           | 31.24a         | 0.53a         |
| P2        | 189.44d        | 23.60c           | 91.38d         | 5.26c         |
| P3        | 165.51b        | 22.10c           | 79.68c         | 3.49b         |

Table 3. The average value of the intensity of green color, root length, wet weight and dry weight of pakcoy mustard plants in each treatment.

Note: Different letters behind the numbers in the same column show significantly different values based on the Duncan test with a level of 0.05.

Combination of Balinese gamelan music gong kebyar and white LED light produced the lowest greenish leaf value, which indicates a lighter green pakcoy mustard leaf compared to other treatments.
This is presumably because the intensity of the white light used for photosynthesis is not optimal [7] state that several factors influence the synthesis of chlorophyll, namely light, water, temperature, genes and nutrients in the soil. According to [6] the higher the green color of a leaf, the higher the chlorophyll content. So that it can be said that the combination of gamelan music gong kebyar and blue-red LED light has a positive result on the greenness of the leaves of the pakcoy mustard. However, the combination of gamelan music gong kebyar and white LED light showed a negative influence on the greenish level of pakcoy mustard leaves.

3.4. Effect of Combination of Gamelan Music Gong Kebyar and LED Light on the Roots Length of Pakcoy Mustard

Analysis of variance indicated that the combination treatment of gamelan music gong kebyar and LED light significantly affected the root length of the pakcoy mustard. The difference in root length in each treatment can be visually seen in figure 5, while the Duncan test results on plant root length can be seen in table 3.

It can be seen from table 3 that the length of the root of the pakcoy mustard resulted from the combination treatment of gamelan music Gong Kebyar and the blue-red LED light was not significantly different than the combination of gamelan music Gong Kebyar and blue-red-white LED light. The combination of Balinese gamelan music gong kebyar and blue-red LED light gives the highest average value of root length compared to other treatments. The combination of Gong Kebyar gamelan music and blue-red LED light increase the root length of pakcoy mustard by 26% compared to controls. This is because the canopy growth of pakcoy mustard plants goes well. According to [3] good growth of plant canopy causes photosynthesis to take place optimally so that food reserves can be translocated throughout parts of the body including roots, resulting in good root growth as well. In addition, gamelan gong kebyar music in the pakcoy plant can widen the opening of the stomata thereby accelerating the absorption of water and nutrients by the roots for photosynthesis. Photosynthesis takes place optimally because it is given red and blue light that can be absorbed by more than 90% by plants [10].

The combination of gong kebyar music and white LED light gives a significantly different value to the other treatments with the smallest root length value. The combination of Gong Kebyar gamelan music and white LED light inhibits plant root growth by 5.7% compared to control. This is because the intensity and wavelength of white LED light is smaller than the control, so that the photosynthesis process does not take place optimally, which causes water and nutrients absorbed by the roots are not maximally utilized for photosynthesis. So it can be stated that the combination of gamelan music Gong Kebyar and white LED light has a negative effect on the root length of the pakcoy mustard.
Whereas the combination of gamelan music gong kebyar and blue-red LED light showed a positive effect on root length of the pakcoy mustard.

### 3.5. The Effect of Combination of Gamelan Gong Kebyar and LED Light on Biomass of Pakcoy Mustard

Figure 6 shows the biomass of pakcoy mustard in each treatment, and the results of analysis of variance are tabulated in table 3. The analysis of variance indicated that the combination treatment of gamelan music gong kebyar and LED light significantly affects the biomass of pakcoy mustard.

![Biomass Chart]

**Figure 6.** Biomass of pakcoy mustard plants in each treatment.

It can be seen from table 3 that the biomass of pakcoy mustard resulted from combination of gamelan music Gong Kebyar and blue-red LED light significantly different with other treatments. This is consistent with the statement of [21] that the treatment of gamelan music can increase the dry weight of pakcoy mustard plants. The same thing was also conveyed by [4], that Balinese gamelan music gong kebyar can increase the productivity of pakcoy mustard [22] states that red and blue LED light has a positive influence on plant biomass.

The combination of gamelan music gong kebyar and blue-red LED light increase the biomass and pakcoy mustard by 36.1% compared to control. This is presumably because exposure of the music to plants can widen the opening of leaf stomata, thus accelerating the entry of carbon dioxide and the rate of absorption of nutrients for photosynthesis which can provide increased photosynthetic accumulation [23]. Biomass is the result of net CO2 assimilation during the vegetative growth period of plants [17].

Thus it can be stated that the treatment of combination of gamelan music Gong Kebyar and blue-red LED light can increase the biomass of pakcoy mustard. Thus it can be said that the treatment of the combination of gamelan music gong kebyar and blue-red LED light has positive results on biomass of pakcoy mustard.

### 4. Conclusion

Based on the results of the study it can be concluded that 1) combination of gamelan music Gong Kebyar and white LED light has a negative effect on the growth and productivity of pakcoy mustard, while the combination of gamelan music Gong Kebyar and blue-red, and blue-red-white red LEDs light have a positive effect on growth and productivity pakcoy mustard. 2) combination of gamelan music Gong Kebyar and blue-red LED light give the best growth and productivity.
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