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# The Effect of Acoustic Exposure on the Growth of Mung Beans *(Vigna Radiata)*

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## ABSTRACT

Sound is a form of wave vibrations that contributes significantly in our daily life. Plants may interact with sound around us but we cannot certainly sure their reaction because of their immobility. Thus, this study intends to find the significant effect between different types of acoustic patterns on the growth of plants. Mung bean or its scientific name, *Vigna radiata* was chosen as seed material in this experiment due to their short growth cycle. The plants were grown in six environmental chambers with proper ventilations. The chambers were placed on open field with ambient conditions. Mung beans were exposed to five different types of acoustic patterns (soprano, classical, nature, rock, Quranic recitation) with sound pressure level of 60 dB ± 10 dB and one chamber was kept without any acoustic exposure. The length of stem, number of leaves and length of roots were recorded on the 15$^{th}$ day of mung beans' growth. Experimental results indicate that different types of acoustic patterns promoted the growth of different part of mung beans. Soprano had significant effect on the length of stem while Quranic recitation promoted the production of leaves. However, there is no significant evidence that acoustic exposure stimulates the length of roots.

*Keywords:* Acoustic exposure, multivariate analysis, mung bean, plant growth

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## INTRODUCTION

Acoustic treatment has broadly attracted attention in many fields. Study has found that audible sound frequency stimulates the protein crystallisation which is beneficial in X-ray diffraction (Zhang et al., 2016). Apart from that, Papoutsoglou et al. (2007) discovered that Mozart's music had resulted in the increase of brain neurotransmitter levels in common carp, *Cyprinus carpio.* Besides, the music also affects their carcass and liver fatty acid composition. Researchers also have proven that the nature of sound could help living organisms in many ways such as soothing moods, stimulating brains (Pereira et al., 2011) as well as treating disease (Naghdi et al, 2015). Living organisms especially human beings are always attracted to music due to its soothing and calming effects on mind. However, have we ever wondered that as living organisms, plants might also be attracted to musical acoustics?

Plant-specific mechanosensory system within plant cells was proposed by Telewski (2006) to be having similarity to the network in animal systems. The sensory network is the capability of plants to react to physical environmental stimuli such as gravity, light, temperature and so on. Hence, plants communicate through numerous kinds of form as well as through sound vibrations (Gagliano et al., 2012). Gagliano (2013) hypothesised that both emission and detection of sound from plants might have adaptive value in plants by affecting responses in other organisms. Under the circumstances, many scientific literatures highlighted the effect of sound frequencies on plant growth. From audible sound to ultrasonic sound, the remarkable effects of those acoustic frequencies on different kind of plants have been reported extensively (da Silva & Dobránszki, 2014; Hassanien et al., 2014). Nevertheless, the effects of musical sound are not widely explored. Musical sound could be described as the sequence of sound in orderly manner to produce symphonic and harmonious sound with rhythmic patterns.

Researchers have found out that Indian classical music gives great influence on the development of plants. Laad and Geetha (2010) investigated the effects of stringed instruments on the fenugreek growth. They used Indian classical music, Sound of Veena and violin sound with frequency of 1.5 kHz and 50 dB to test. Through biochemical analysis, chlorophyll contents, carotenoids, carbohydrates and protein had increased in plants exposed to stringed instruments. Meanwhile, Chivukula and Ramasamy (2014) suggested that Vedic chants and Indian classical music were ideal choice to promote the growth of *Rosa chinesis* while Rock music creates havoc thus preventing the plants from growing.

Recent research by Alavijeh et al. (2016) had discovered that different types of music had significant effects on cowpea plant. Classical music had great impacts on cowpea but noise, techno and traditional music completely gave negative effects. Similar result was obtained when soft and smooth music was exposed to eight medicinal and ornamental plants and it was reported that flowering time occurred a week earlier with the presence of music (Sharma et al., 2015). In addition, Ekici et al. (2007) concluded that plant grew faster under positive music because they discovered that length of adventive roots of onion were longer under music stimulation. The root elongation of onion was being identified to be associated with cell metabolism because roots could be considered as the brain to plants where they controlled the plants' systems.

However, there is inconsistency in the argument that rock music gave negative impact on plant growth where Vanol & Vaidya (2014) discovered that both silent classical music and rhythmic rock music showed better result whereas traffic noise showed destructive effect on the growth of common guar. In contrast to that, it was revealed that both violin music and traffic noise gave positive impacts on the number of leaves and heights of common bean plants (*Phaseolus vulgaris*) (Chatterjee et al., 2013).

Hence, this research was conducted with the aim of validating that musical acoustics could be supplement of chemical fertilisers to facilitate their growth. For that reason, application of audible sound on plant has been discovered to be a clean solution, acting as physical fertiliser for plant growth (Weiming et al., 2015). Hence, this study was carried out to find how different types of acoustic patterns could promote the growth of mung beans. The usual genre of acoustic patterns from previous researches such as classical and rock music was chosen. Nature sound was considered in this experiment as it was stated that natural sounds produced by animals such as buzzing of bees, chirping of birds and crickets sounds also helped in growing plants (Appel & Cocroft, 2014). Moreover, as pure tone of high audible sound frequency has been found to stimulate mung beans (Cai et al., 2014), soprano music was chosen to be part of acoustic exposure due to its high tone frequency. Soprano is rhythmic sound coming from the highest pitch of human vocal meanwhile classical is rhythmic sound from instruments which commonly has lower frequency than soprano. Besides, Quranic recitation related to plants was also being chosen to find the significant effect on mung beans. Quranic recitation was also being considered in this study because it is also rhythmic sound coming from vocal of Quran reciter. Furthermore, it was discovered that Quranic recitation gave positive effects which could be a healing medium for cell cultures (Hashim et al., 2017).

## MATERIALS AND METHODS

### Seed material

The plant used for the experiment was mung bean. Mung beans were used as the tested seed material because of their short growth cycle. Thus, their physical growth development could be monitored easily within the period of experiment. Australian mung bean seeds (120) with similar shape and size were selected randomly.

## Experimental Design

The experiment was conducted based on completely randomised design (CRD). The independent variable considered in this experiment was acoustic pattern and the dependent variables were measured based on length of stem, number of leaves and length of root. Mung bean seeds (Total =120) were selected randomly and they were left to be soaked in water for eight hours to ensure that all seeds would germinate and grow. Lab certified nursery trays (Total =24) with dimension of 44.45 cm x 20.32 cm were used to grow the selected mung beans. For each tray, a total of five seeds were planted in it with 2.54 cm in depth and a distance of 7.62 cm from each other.

Six environmental chambers had been customised and set up as shown in Figure 1. The chambers were made up of 1 cm transparent acrylic with the dimension of 93 cm x 57 cm x 80 cm. They were equipped with fans for proper ventilations which regulate the air movement inside the chambers. Automatic irrigation has been developed so that the watering time would be automatically started at 9.00 am, 1.00 pm and 5.00 pm every day for a period of two minutes for each respective time. Temperature and humidity sensors had been fitted to the chamber and the data logged could be monitored online. The data was not directly used in the analysation but to monitor if there was any variation in both temperature and humidity between all chambers. The temperature and humidity in all six chambers were recorded to be maintained at 28.6±2.4ºC and 80±10% respectively.

All six chambers were placed on open field with ambient conditions as shown in Figure 2. Four nursery trays were placed in each environmental chambers which 20 mung bean seeds were grown in each chamber. Five audible acoustic patterns were used in the experiment and the acoustic patterns were assigned randomly to all environmental chambers as represented in Figure 3. One chamber was left without any acoustic treatment to act as control group. The acoustic patterns were exposed to mung beans in respective chambers every day for three hours automatically played from 9.00 am. The exposed acoustic patterns were nature sound, rock music, Quranic recitation, soprano and Western classical music. The acoustic patterns were played with sound pressure level (SPL) of 60 ± 10 dB as it was within medium range of SPL.

Mung beans were left to grow for 15 days and their growth were observed every three days interval. The length of stem and the number of leaves were measured in every observation and the changes were noted. On the 15th day, mung bean plants were harvested to measure their growth indexes. The growth indexes that were taken into account in this experiment were length of stem, number of leaves and length of roots. Length of stem and length of roots were measured using 3 m x 19 mm Mr. D.I.Y measuring tape.

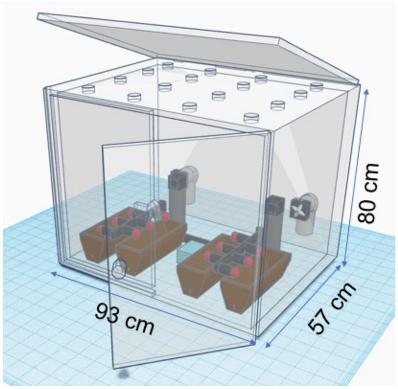


*Figure 1*. Drawing of environmental chamber

*Figure 2*. The location site of experiment

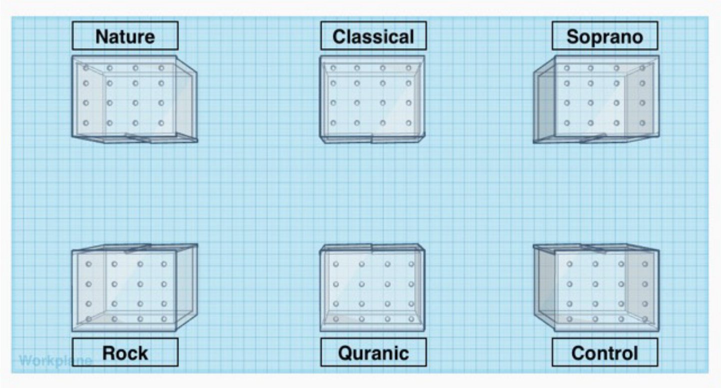


*Figure 3*. Arrangement of chambers with respective acoustic patterns

## Data Analysis

Data collected on day 15 were analysed based on multivariate analysis. In this experiment, acoustic pattern was accounted as independent variable and the dependent variables were length of stem, number of leaves and length of roots. Hence, one-way multivariate analysis of variance (MANOVA) was conducted to find the effect of different types of acoustic patterns on the growth indexes mentioned. MANOVA is chosen as the method of analysis because it assesses the effect of independent variable on more than two dependent variables simultaneously. Thus, this will reduce the chance of committing type I error.

Before performing MANOVA, we had to make sure the data recorded met the assumptions required for the analysation method. For MANOVA, the data for dependent variables must be normal, equal in covariance matrices and correlated to each other. Microsoft Excel and IBM SPSS Statistics are the software tools used in recording and analysing the data.

## RESULTS AND DISCUSSION

The growth indexes of mung bean plants were measured on day 15 of the experiment and their physical growth were as shown in Figure 4. Table 1 shows the mean and standard deviation of data collected for each treatment of acoustic patterns on the growth of mung beans (length of stem, number of leaves and length of root).

Based on the output obtained in Table 1, the maximum length of stem was seen on mung beans exposed to soprano. Classical, nature and rock music also stimulate the length of stem but not as much as Soprano and Quranic recitation. The average stem length of the plants exposed to soprano, classical, nature, rock, Quranic recitation and control group in centimetres were 15.13, 13.63, 13.16, 12.92, 13.79 and 12.88 respectively. This showed that the increase of length of stem was maximum in mung bean plants exposed to Soprano, followed by Quranic recitation, classical, nature, rock and lastly control group.

For number of leaves, Quranic recitation had greatest impact on the yield of leaves on mung beans with average of 7 leaves. This followed by rock, control, soprano, nature and the least number of leaves on plants exposed to classical music. However, the average length of roots in centimetres of mung bean plants on the 15th day for soprano, classical, nature, rock, Quranic recitation and control group was 15.83, 20.32, 22.55, 22.35, 19.71 and 20.95 respectively. This indicates that the length of roots was highest in plants exposed to nature sound followed by rock, control, classical, Quranic recitation and the least affected in soprano.

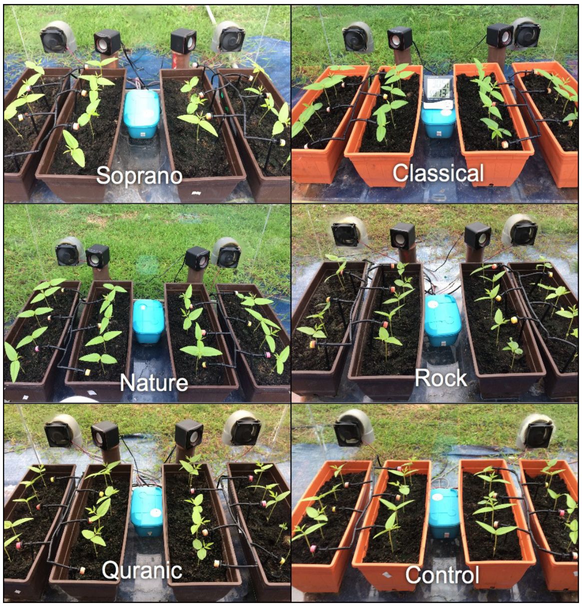


*Figure 4*. The growth of mung beans for day 15 with respective acoustic exposure

Table 1
*Mean and standard deviation of experimental data*

| Growth Index | Acoustic Pattern | Mean | Standard deviation |
|---|---|---|---|
| Length of stem | soprano | 15.13 | 3.42 |
| | classical | 13.63 | 1.34 |
| | nature | 13.16 | 2.35 |
| | rock | 12.92 | 1.81 |
| | Quranic | 13.79 | 2.20 |
| | control | 12.88 | 1.94 |
| | Total | 13.57 | 2.34 |
| Number of leaves | soprano | 6.58 | 1.84 |
| | classical | 5.60 | 1.23 |
| | nature | 6.00 | 1.52 |
| | rock | 6.95 | 1.47 |
| | Quranic | 7.00 | 1.45 |
| | control | 6.80 | 1.51 |
| | Total | 6.49 | 1.57 |
| Length of roots | soprano | 15.83 | 9.99 |
| | classical | 20.32 | 13.03 |
| | nature | 22.55 | 12.40 |
| | rock | 22.35 | 10.82 |
| | Quranic | 19.71 | 10.89 |
| | control | 20.95 | 11.14 |
| | Total | 20.32 | 11.41 |

Table 2 summarises the mean of growth indexes from highest to lowest ranking with 1 as the indicator of highest until 6 as the indicator of the lowest. From the sum of rank, the highest is Quranic exposure while the lowest is classical music. Thus, it indicates that Quranic recitation could be best in promoting growth of mung beans. However, ranking them is the only rough analysis on what is going on with the data. Thus, further statistical analysis has been conducted to find the significant effect.

Hence, a thorough analysis has been done for the data recorded using MANOVA. Before performing MANOVA, checking the required assumptions is essential. Table 3 shows the results of three statistical tests conducted to check whether the data meet the assumptions required. Firstly, the normality of the data recorded was tested using skewness. Referring to Table 3, length of stem data (-0.869) and length of roots data (0.612) are moderately skewed while the data of number of leaves (0.164) is fairly symmetrical based on (Bulmer, 1979). Hence, data of growth indexes passed the normality test.

Table 2

*Sum of rank of mean of growth indexes for each acoustic pattern*

| Growth Index | Soprano | Classical | Nature | Rock | Quranic | Control |
|---|---|---|---|---|---|---|
| Length of stem | 1 | 3 | 4 | 5 | 2 | 6 |
| Number of leaves | 4 | 6 | 5 | 2 | 1 | 3 |
| Length of roots | 6 | 4 | 1 | 1 | 5 | 3 |
| Sum of rank | 11 | 13 | 10 | 9 | 8 | 12 |

Table 3

*Statistical Tests for Checking Assumptions*

| Normality Test using Skewness | | Box's M Test | Bartlett's Test of Sphericity |
|---|---|---|---|
| Dependent variable | Skewness statistics | *p*-value | *p*-value |
| Length of stem | -0.87 | | |
| Number of leaves | -0.16 | 0.13 | 0.00 |
| Length of roots | 0.61 | | |

Next, we checked the second assumption which was the equality of covariance matrices using Box's M Test. From Table 3, the *p*-value reported is 0.13 which is $p>0.05$. The insignificant result of this test indicates the homogeneity of covariance matrices. Thus, the data met the second assumption of MANOVA.

Moving on to test the third assumption of MANOVA, Bartlett's Test of Sphericity was chosen to find the correlation of all dependent measures. The correlational of dependent measures are crucial in MANOVA method as there is no use of conducting this method when all dependent variables are not correlated at all. As in Table 3, the *p*-value reported is $p<0.05$ which is significant. Hence, there is sufficient correlation between the dependent variables. So, the data met all three assumptions and MANOVA method could be conducted.

Table 4 shows the result obtained for multivariate test (MANOVA), showing only Wilk's lambda test and analysis of variance (ANOVA).

We could see that multivariate effect was significant by levels of acoustic patterns with $F(15, 306.82)= 2.382$, $p<0.05$. Hence, there is significant effect in growth indexes (length of stem, length of roots, number of leaves) between six different types of acoustic patterns (soprano, classical, nature, rock, Quranic, control).

Then, we went through the univariate analysis of the data. From Table 4, there is insufficient evidence to show that length of roots was affected by acoustic exposure. However, there is sufficient evidence to conclude that acoustic patterns have significant effect on length of stem and number of leaves with $p<0.05$. Hence, we were interested in comparing all pairs of acoustic treatment means and the null hypothesis that we wished to test was $H_0 = \mu_i = \mu_j$ for all $i \neq j$.

Table 4
*Multivariate Analysis of Variance (MANOVA) and Analysis of Variance (ANOVA)*

| | | | | |
|---|---|---|---|---|
| MANOVA | Source of variation | Value of Wilk's lambda | F | *p*-value |
| | Acoustic pattern | 0.738 | 2.382 | 0.003 |
| ANOVA | Source of variation | Dependent variable | F | *p*-value |
| | Acoustic pattern | Length of stem | 2.69 | 0.03 |
| | | Number of leaves | 2.82 | 0.02 |
| | | Length of root | 0.89 | 0.49 |

According to Tukey HSD, we could reject the null hypothesis saying that there is significance difference between pairs of acoustic treatment means. Referring to Table 5 which shows the result of post-hoc test, there is significance difference between classical and Quranic with mean number of leaves of 5.6 and 7.9 respectively. As for length of stem, the significant difference could be seen between soprano and rock, soprano and control.

Soprano is significant to promote length of stem might be because of its sound characteristics which has highest frequency compared to other acoustic patterns. This finding reinforces with research from Cai et al. (2014) who found out that higher sound frequency promoted the elongation of stems and roots. As soprano and Quranic recitation are significant in promoting length of stem and number of leaves respectively, their mechanism might be happened as those acoustic patterns stimulate the opening of stomata as mentioned by Meng et al. (2012). This opening of stomata might facilitate the absorption of water and light intensities which promotes the elongation of stem and increasing number of leaves. However, this study could not provide enough evidence to prove that acoustic pattern could increase length of root as mentioned from previous studies.

Table 5
*Multiple Test Comparison based on Tukey HSD Post-Hoc Test*

| Dependent Variable | (i) Acoustic pattern | (j) Acoustic pattern | Mean difference (i-j) | *p*-value |
|---|---|---|---|---|
| Length of stem | soprano | classical | 1.50 | 0.31 |
| | | nature | 1.97 | 0.08 |
| | | rock | 2.21* | 0.03 |
| | | Quranic | 1.34 | 0.44 |
| | | control | 2.25* | 0.03 |
| Number of leaves | classical | soprano | -0.98 | 0.34 |
| | | nature | -0.40 | 0.96 |
| | | rock | -1.35 | 0.06 |
| | | Quranic | -1.40* | 0.05 |
| | | control | -1.20 | 0.13 |

## CONCLUSION

As the deduction, it is clear that acoustic patterns have significant effects on the growth of mung beans in terms of growth indexes measured. Hence, it is true that plants pick up the vibrations around them. The significance showed that plants do react to acoustics. It is found that soprano could help promoting length of stem the most while Quranic recitation could help stimulating number of leaves. However, there is no sufficient evidence to conclude that acoustic patterns affect length of roots. Hence, different types of acoustic patterns have affected the growth of tested material on different part of growth system. Since it is reported that acoustic treatment could affect the length of stem and number leaves, the treatment could be applied in agricultural field as the supplemental contributor to improve the development of plant growth. Thus, we can consider those significant acoustic treatments for plants that need higher length of stem or higher production of leaves.

This findings might be noteworthy in agricultural field which we can get benefit out of it. Hence, musical acoustics can act as the supplemental effect to facilitate plant growth. However, further research should be done to validate this findings. As this study only focused on physical growth of mung beans, we suggest that our significant acoustic patterns of soprano and Quranic exposed to mung beans be tested for their biochemical effects and conclude on how actually their interactions lead to higher length of stem and number of leaves.

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