THE EFFECT OF SOUND ON THE GROWTH OF PLANTS

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ABSTRACT

This project is intended to show how the rate of growth of two different plant species was affected by sounds of varying frequencies. Two plant species, beans and impatiens, were selected because of their relatively fast growing rates. Ambient conditions were regulated by environmental chambers in which the plants were housed. One chamber was used as a control for the plants, and the plants in the other chambers were subjected to sounds of different frequencies at roughly the same sound intensity. Sounds of pure tones and random [wide band] noise were used. The changes in the growth of the plants were monitored every two days for twenty-eight days. Upon completion of the tests, it was observed that optimum plant growth occurred when the plant was exposed to pure tones in which the wavelength coincided with the average of major leaf dimensions. It is suggested that this was due to the "scrubbing" action of the traversing wave, causing air particle motion on the surface of the leaf; this movement removed the stagnant air layer adjacent to the leaf, thus increasing the transpiration of the plant. It was also noted that the plant growth was less when exposed to random noise.

SOMMAIRE

Ce project avait pour but de montrer comment le taux de croissance des deux espèces de plantes être influé par une varieté d'ondes sonores. Les deux espèces, des haricots et des impatiens, ont été choisis à cause de leur croissance rapide. Les plantes furent placées dans des sailles donc les conditions ambiantes étaient réglées selon les critères environnmentales. Une salle servit de contrôle pour les plantes. Dans les autres salles, les plantes furent exposées à divers ondes sonores d'environnment à la même intensité. Des ondes sonores claires et croissant au hazard furent difusées. Les taux de croissance furent servi des près. C'est à dire, à tout les deux jours jusqu'au visit-huitième jour. A la fin de ces tests, nous avons observé été la croissance optimum a eu lieu dans les plantes exposèes aux ondies sonores claires, et que la longeur des ces ondes coincidait avec la dimension moyenne des feuilles. On suggère que ceci s'est produit quand les ondes sonores ont "balayé" les particules dans l'air sur la surface de la feuille. Ce dèplacement d'air stagnnat attenant la feille permet ensuite à celle-ci d'augmenter la transpiration végétale. Aussi, nous avons observé une baisse de croissance dans les plantes exposées aux ondes sonores choisies au hazard.

1. INTRODUCTION

Very little research has been conducted on the specific effect of the growth of plants subjected to sounds of varying intensity and frequency. Any environmental factor that places a biological system under stress can affect its performance and/or behaviour. The effect of sound on physiology and behaviour of animals and man has been studied by various researchers [1, 2, 3, 11, 13, 14]. However, only a limited amount of detailed information is available on the effect of sound on plant systems [4, 8, 9, 10, 12].

An article entitled "The Effect of Noise on Plant Growth" [4], stimulated an interest in further research in this field. The author, A.E. Lord, performed random noise experiments on coleus plants in which one group was subjected to random noise and a second group was used as a control. Lord came to the conclusion that botanists had not carried out sufficient experiments to show causes behind the effects that he observed, and he put forward the idea that the rate of water transpired out of the leaves is affected by the sound. Transpiration, in turn, affects growth. Typical leaf structures and the topic of transpiration can be found in textbooks on botany [e.g. reference 15, 18, 19, 20].

It has been reported [5, 6, 7] that music will increase plant growth, but it is not known what preferred frequencies (if any) in the music have the most pronounced effect on plant growth. Many of the papers (see above) had very little detail about the conditions under which the plants were grown, how conditions were controlled [or if they even were controlled], and exactly how the growth rates were monitored.

Singh and Ponniah [5, 6] were two of the pioneers in this work. They played obscure violin pieces intermittently to plants at certain times of the day, and they occasionally made use of tuning forks as the sound source. Very seldom, if ever, were the experimental methods or type of analysis revealed. Generally, a table of results was presented and it was left to the reader's imagination to determine how these results were obtained. Singh's work was referred to extensively in the original article by Lord. Very little constructive information was obtained from this source.

One of the more amusing accounts of sound tests on plants appeared in the May 1993 issue of Popular Mechanics, entitled "Growing Corn to Music" [7]. It was seen that the "music" plants sprouted faster, were greener, and their stems were thicker and tougher than the "silent" plants. Although the results were interesting, this article is not scientifically grounded.

An interesting paper was obtained from the Internet by Bruce M. Pixton, titled "Plant Growth in a Sound Polluted Environment" [12]. He did not use environmental chambers, but built a box with three side-by-side sections with soil in the bottoms; one section was used for control seeds, and the other two were subjected to sounds (pure tones and random) from audio speakers at the bottom of each partition under the soil. The loud sounds were audible in the room. He played sounds of 5,000 Hz and 13,300 Hz to alyssum seeds, both before their germination and after they had sprouted. He compared the number of seeds sprouted and the sprouts which were 2 cm or taller with the control group of seeds, all under similar ambient conditions, i.e. room conditions and light from a window. He concluded that loud, high frequency, sound tones increased the rate of plants sprouting and growth. He noted that the random noise had the opposite effect. He did not venture a reason for this.

Pearl Weinberger and Mary Measures, at the University of Ottawa [8, 9], experimented with spring wheat [Marquis] and winter wheat [Rideau], exposing the plants to varying frequencies either during the germination period, or during the growth period, and sometimes during both periods. They observed a marked increase in the growth stimulation of plants treated with 5 kHz sound when compared with controls (with no sound). In these experiments, their time was limited, and hence it was thought that their results were not extended over a sufficiently long period of time.

The only other paper with any relevance to this project dealt with the effects of random noise on tobacco plants [10]. Woodlief, Roysier and Huang, did not use a control group as the technique of determining the growth rate for tobacco plants. It was found that there was a significant decrease in the slope of the growth rate curve after the noise was imposed, and the conclusion was that the random noise environment was detrimental to the growth rate of the plants. To quote from their paper, "the sensitivity of the plants to the random noise environment seemed to be coupled with initial plant size in that the smaller plants seemed to be more sensitive to this environment".

Many of the papers from the literature did not have applicability to this experiment, as was the explanation of results. However, Lord's idea about the rate of water transpired out of the leaves being affected by the sound provided the basis for the analysis made in this paper.

2. APPARATUS AND PROCEDURE

The plants were housed in environmental chambers, 162 cm high, 153 cm wide, 84 cm deep with 2 cm thick walls [Figure 1]. The environmental chambers were made by Percival Co. of Boone, Iowa, U.S.A. They controlled the temperature and

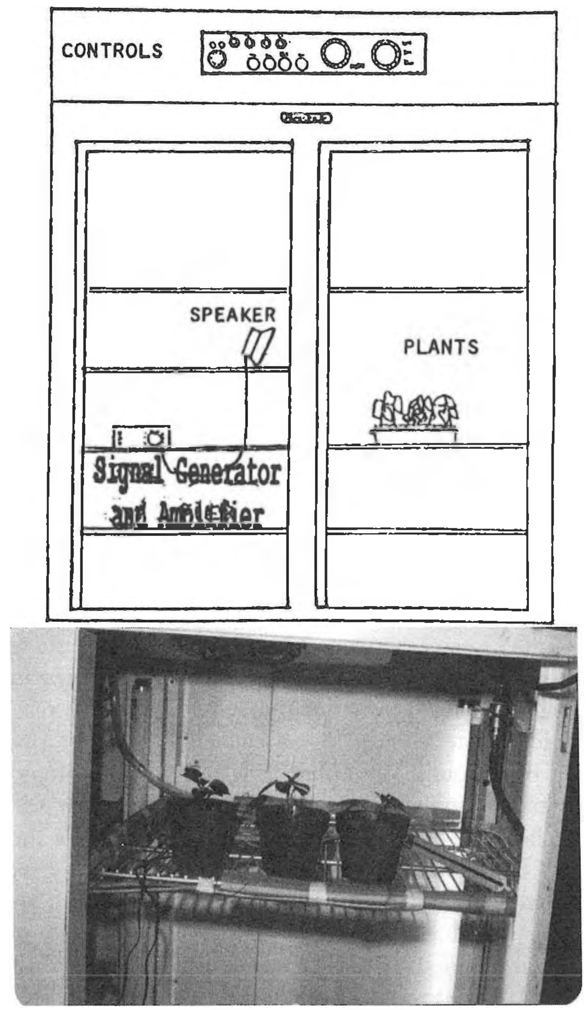

Figure 1. Environmental Chamber

lighting, and provided a constant flow of air by means of in-built fans and vents. The operating specifications of the chambers were: Photoperiod: DAY/NIGHT; Thermoperiod: 0 to 150 degrees F / 15 to 65 degrees C; and Fluorescent lighting: 6 tubes, cool white, 40 W

The chambers had separate controls to regulate light intensity, temperature and airflow. There was minimal air movement in the chambers. Either two or three of these chambers – all identical – were used during the twenty-eight day test period. The watering rate of the plants was monitored manually using a graduated cylinder. The sound was produced by a signal generator, amplifier and a speaker, which were placed inside the chamber [see Figure 1]. Each signal generator had a range of twenty to twenty thousand Hertz [cycles per second-Hz] and was capable of producing the frequency as a single sine wave or as a mixture of frequencies over a range [equal energy per unit bandwidth – white or random noise]. These signal generators and amplifiers were constructed by the Electronics Shop of the Faculty of Engineering Science. The speakers were co-axial, made by Altec and capable of a frequency response of twenty to fifteen thousand Hz. The sound pressure level was the same in all of the chambers, and averaged 91 to 94 decibels, measured on the linear scale with a Bruel and Kjaer Sound Level Meter and a one-half inch microphone. These measurements were taken at eight different positions around the plants, averaged, and monitored regularly. [See reference 16 for a description of the meter and microphone.]

The Plant Science Department at The University of Western Ontario offered its services in helping to set up an experiment, in choosing suitable plants, providing the environmental chambers, and helping to analyze the results. The Sound and Vibration Laboratory of the Faculty of Engineering Science provided the sound generating and measuring equipment.

The impatiens plants were started from cuttings four weeks before the start of the test days. From four to eight of the plants were used in each test. Cuttings from one impatiens plant were taken initially and placed in the potting beds in the greenhouse. All of the impatiens plants used later in the experiments were propagated from these initial cuttings. To take cuttings from the same plant is the only way to get plants as genetically close as possible [15]. This is termed cloning and is a fairly important genetic control. The beans, Dwarfbush Stringless Green Pod, were grown from seed seven days before the experiments started. It was not necessary to use cuttings from beans; they grow rapidly. Again, four to eight plants were housed in each chamber, along with the impatiens plants, during the testing.

It should be noted that, even though there was a reverberant sound field in the chamber [due to reflections], it is believed that the major sound which affected the plants was in the direct path of the sound from the speakers. This can be seen in the schematic drawing in Figure 1, and is explained in detail in References 1 and 13. (See Conclusions and Recommendations with regard to further study.)

Due to the fact that there was a minimum of space in the chamber, which was in the direct path of the sound, only two different species of plants were tested in each chamber. Ideally, a larger number of different species should have been tested, as the results may not be generally applicable to all kinds of plants. The ones used in this project were both green and leafy, and anything that was happening in the leaves or stem would be reflected in the subsequent height of the plant. Seven groups of plants were tested. The first four tests of sound experiments were chosen randomly. It was decided to test with random noise, a low frequency sound [500 Hz] and other higher frequency sounds. Those chosen were 5,000 Hz and 12,000 Hz. For reasons discussed later, 6,000 Hz and 14,000 Hz were selected as the last two frequencies to be tested.

The plants were watered daily, each species receiving the same quantity of water. The height measurements were taken every two days with the plant extended to its full length, and recorded. The measurements were taken over a twenty-eight day testing period.

3. DISCUSSION AND OBSERVATIONS

At the outset of these experiments, it was reasoned that there might be a relationship between the wavelength of the sound generated and a characteristic dimension of the leaf.

Figure 2 represents the outline of a bean leaf, and there is a small particle of air moving back and forth on the surface of the leaf with velocities of positive and negative "u" [11, 13]. This wave movement occurs as a result of the diaphragm of the speaker moving back and forth, setting up a travelling compression and rarefaction wave. The compression results

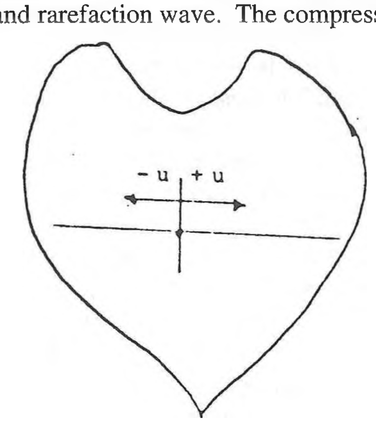

Figure 2. Sound Propgation along a leaf

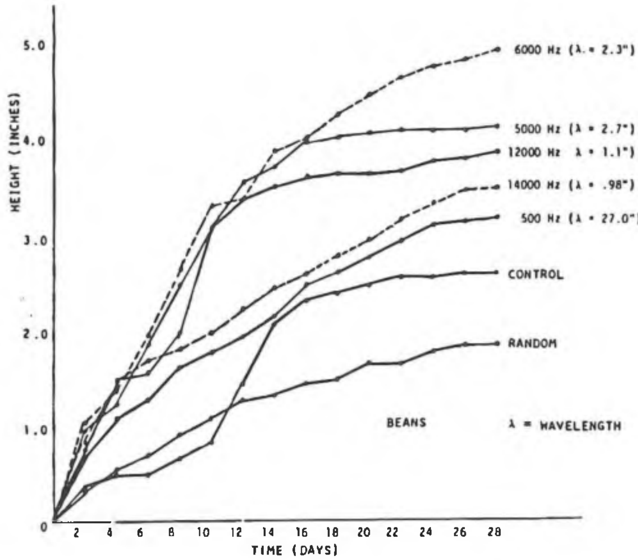

Figure 3. Plant Growth Characteristics Curves for Bean Plants

in a positive pressure [above atmospheric] and the rarefaction in a negative pressure [below atmospheric]. This is propagated across the surface of the leaf and is commonly represented as a sinusoidal air pressure variation. The particle velocity is proportional to the sound pressure [13], and a positive pressure results in a positive particle velocity, the magnitude of the velocity being proportional to the pressure at any point as it moves across the leaf. The same process results from a negative pressure, only with the particle velocity in the opposite direction. This creates a scrubbing or brushing action on the surface of the leaf, which wipes away any stagnant film of moisture and allows the plant to breathe [transpire] more freely [15, 19].

The first four sets of sound results obtained, which were for the random noise, 500 Hz, 5,000 Hz, and 12,000 Hz, seemed to bear out the contention that the relationship between the frequency [and its wavelength] and the dimension of the leaf had some effect [Figures 3 and 4]. The average dimension for the bean leaf [measured from the control group] gave values of 2.4 inches by 2.4 inches. A wavelength of 2.4 inches corresponds to a frequency of 5,600 Hz for the given conditions. The best results for the beans had been for 5,000 Hz [wavelength = 2.7 inches], so that 6,000 Hz was chosen as one of the two remaining frequencies to be tested. It has a wavelength of 2.3 inches and, as can be seen in the results [Figure 3], gave the best growth curve for the bean plants.

The average dimensions for the impatiens leaf [again measured from the control group] gave values of 1.0 inch by 1.7 inches. A wavelength of 1.0 inch corresponds to a frequency of 13,500 Hz and the 1.7 inches to a frequency of 8,000 Hz. For the impatiens, the best results had been for the 12,000 Hz frequency [wavelength = 1.1 inches], so the 1.0 inch dimension was narrowed in on [average width of leaf] and a frequency of 14,000 Hz was chosen with a wavelength of .98 inch [Figure 4]. This gave the best results for the impatiens plants.

When the growth changes, measured every two days, were plotted for the complete test period and all frequencies, the growth characteristic curves resulted [Figures 3 and 4]. The horizontal axis represents the time in days and the vertical axis the height in inches.

Higher frequencies, and hence smaller wavelength, would result in a wave with more nodal points on the leaf, which are points of zero pressure with respect to atmospheric, or points of zero velocity. This means that there are more places on the leaf surface where the film of moisture is not being removed. These higher frequencies were tested for the beans, and the results were not as good as the results for the higher frequencies close to the preferred one where the wavelength was approximately equal to the dimension of the leaf [Figure 3].

One might suspect that a wavelength that corresponds to two times the dimension of the leaf might give the best results. This has the least number of these nodal points, but there was insufficient time to test this idea.

As a result of previous work, it was expected that the effect of the random noise on the plants would cause a decrease in their growth rate [10]. Any experiments to date have found that this is the manner in which plants respond to random noise [4, 10 and 12]. The bean plants [Figure 3] responded as expected, but the impatiens plants [Figure 4] showed an improved growth rate [as compared to the control group].

Woodlief [10] did observe that the smaller tobacco plants

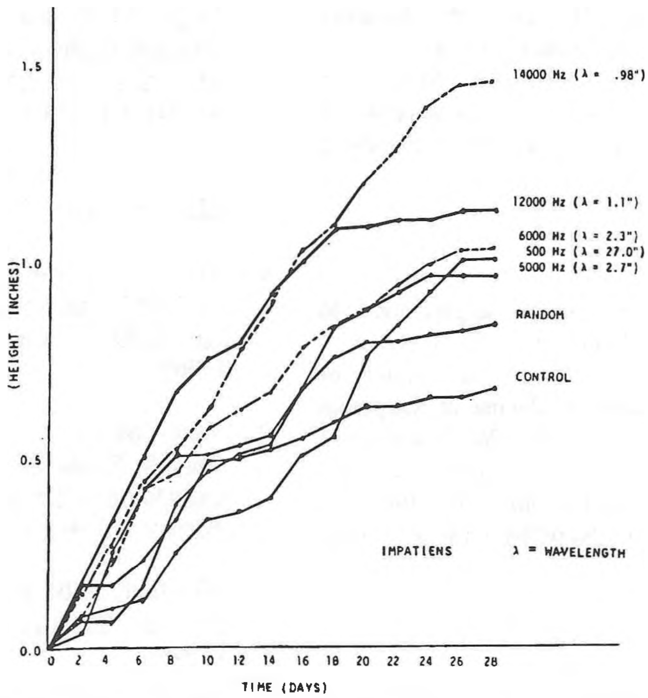

Figure 4. Plant Growth Characteristics Curves for Impatien Plants

that he tested were more affected by the sound. In this experiment, the beans were just beginning to germinate at the outset of testing, while the impatiens plants were well developed at four weeks. This could be the reason for the more pronounced effect on the bean plants. Had the testing extended further, it is possible that the random noise impatiens' growth rate would fall below that of the control group. This points warrants further investigation.

A statistical analysis of the results, as carried out by Wai Keung Li of the Faculty of Social Science, is given in reference 17. This analysis showed that of the fixed frequencies, random frequencies and control, the fixed frequencies have a significant effect on plant growth when compared with random frequencies and the control.

4. CONCLUSIONS AND RECOMMENDATIONS

From the results of the experiments as shown in Figures 3 and 4, it is clear that, in time, i.e. after 28 days of testing, the optimum growth of both the beans and the impatiens plants occurred when the wavelength of the sound coincided with the plant leaf dimension. This conclusion cannot be drawn for the growth periods of up to about 16 days. Below this the results are mixed and inconclusive. It should be noted that, for the beans, the growth with the random noise was less than the growth with any of the pure tones. There was not this marked difference between the growth in the impatiens plants when subjected to random and pure tones [Figure 4]. In the latter days of the testing, growth with the random noise was less with the bean plants [Figure 3] than with the impatiens plants [Figure 4]. This is something that warrants further testing, especially with a larger number of plants, perhaps a larger species variety, and a longer testing period.

It might be assumed that the growth rate of the plants when exposed to pure tones [with a wavelength coincidental with the leaf width] at a higher sound pressure level [above 90 decibels] would be even greater than measured in these experiments. Further, it is noted that the sound tone frequency where the wavelength equals twice the plant leaf dimension might be tested to determine if this would be the optimum frequency for the best growth results. These points should be investigated in further studies.

It should be noted that the correlation between wavelength and leaf size, and resulting increase in transpiration, is but one potential explanation of the observed plant growth. However, there are many physiological processes at play in the general phenomenon of growth. The effects of sound wavelength under several regimes of light intensity and relative humidity should be studied; physiologically, it would be interesting to explore the potential effect of sound wavelength on the rate of extension of the leaf after it is formed; and biochemically, it would be interesting to look at the effect of sound wavelength on the rate of photosynthesis in leaves of varying ages.

In addition to the recommendations mentioned above, there is a further aspect of the study which bears investigation. It was assumed that the effect of reflection in the chambers would be of little consequence because the plants were placed in the direct path of the sound from the speaker. Ideally, the tests should be conducted in a non-reverberant environment (i.e. an acoustical or semi-acoustical chamber).

5. ACKNOWLEDGEMENTS

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6. EPILOGUE

This work was conducted in 1979 by Margaret E. Collins while she was a student in Mechanical Engineering at the Faculty of Engineering Science of The University of Western Ontario. I was her supervisor and we were assisted by the Department of Plant Sciences at the University [see Acknowledgements]. The work was recorded in her thesis as part requirement for ES 400 - Project, Thesis and Seminar. Ms. Collins is now deceased and this paper is written to her memory.
John E.K. Foreman, Professor Emeritus, May, 2001

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