Understanding Plant Bioelectric Responses in Basil Plants to Environmental Change

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Abstract

This experiment focused on determining the effect of auditory stimuli on biological growth and the bioelectricity of the plant named Ocimum basilicum, otherwise known as basil. The research work covered three different auditory stimuli; that is, Islamic Adhan call for prayers, sonata from the violin by the famous composer Johann Sebastian Bach whose frequency tone was 432 Hz, and natural sound from the environment. The purpose of conducting this study was to determine the effect of auditory stimuli on the bioelectric activities and the growth of leaves of the basil plants. This study involved the use of quantitative approach in research whereby real-time data was obtained from the plants over a period of three weeks or four weeks. In this experiment, the fifteen plants were evenly divided into three groups and exposed to various auditory stimuli every day for fifteen minutes. In order to measure bioelectrical signals in the plant, the Plant SpikerBox device was employed while measuring the growth of the leaves was done every three days. From this study, it is evident that the plants exposed to violin sonata and Islamic Adhan had higher bioelectrical activities and leaf growth as compared to those exposed to environmental sounds. The results obtained from this experiment agree with previous research in which vibrations produced in the sound waves can serve as stimuli for the environment with an effect on the physiology and electricity of the plants. This experiment has made a significant contribution to the field of electrophysiology of plants by studying the effects of sound waves generated from different societies and music on plants within the UAE environment.

Keywords: Ocimum basilicium, bioelectric signals, auditory stimuli, plant electrophysiology, Plant SpikerBox, Islamic Adhan, plant sensory biology

Contents

Introduction

Animals have specialized auditory organs, like ears, which enable them to be highly sensitive to sound, while plants do not have any such obvious organs. As sessile organisms, plants may be viewed as being minimally influenced by sound signals. However, the study found that plants have a critical, if somewhat hidden, connection with sound which is key to their growth and wellbeing. The range and level of biotic and abiotic stimuli that they can "feel" and react to is not a luxury but a necessity for their survival. Although plant responses to light, temperature, touch, and chemicals have already been well-studied, sound-related effects, at least those that are evident and relevant enough to significantly affect growth and development, are still scant in the scientific community. This ignorance provokes essential research questions regarding whether sound may function as a meaningful external environmental cue capable of modulating internal plant processes instead of being perceived as a neutral external factor. This sensitivity could have a physiological basis in bioelectric plant properties. As Plant Electrophysiology: Volkov (2012) suggests, the synchronization of plants' internal processes with external events in the environment is the plant equivalent of excitability. This phenomenon may be a potential mechanism by which a plant's physiological processes and growth can be influenced by outside acoustic vibrations, regardless of their origin.

Statement of the Problem

One of the most controversial issues in plant science is whether sound waves affect plants. Research into this topic has been limited, particularly in the Middle East. It is unknown whether other types of acoustic stimuli, e.g. Islamic Adhan or music genres establish specialized electrobiological and productivity behaviors in plants. This knowledge gap limits the development of sound-based agricultural strategies and our understanding of the biology of plant sensory perception. This obstacle is consequential as plants depend on surrounding signals for growth, development, and responses to tension. Incomprehension on whether sound can serve as one of these signals hinders scientists and agricultural professionals from establishing sound-based techniques that are both reliable, sustainable, and financially accessible to improve crop efficiency. Furthermore, the limitations in number of regional studies means that discoveries from around the world may not accurately apply in Middle Eastern atmospheric conditions and terrains, creating an important gap in cultivation research within this region. Recent research supports the idea the plants are responsive to sound, as Melo (2023) reports that plants can detect and respond to vibrations; however, the bioelectrical mechanisms underlying these responses remain incompletely explained.

Research Objectives

This study intends to identify how Adhan and different sounds can either enhance or diminish the growth rate of certain species of plants. Therefore, this study will explicitly investigate the results of differentiating sound vibrations on the bioelectric potentials of certain plant species.

Research Questions

- What is the effect of the Islamic Adhan on the growth and bioelectric activity in basil plants?
- How do different acoustic stimuli impact basil plant physiological and electrical responses?

Relevance of the Study

Although various studies have documented the outcomes of sound vibrations on certain observable traits such as germination efficiency and total biomass, this study will explore the early bioelectric signals that may initiate these changes. This research hypothesizes that mechanical vibrations from sounds are converted into bioelectrical signals within plant tissue, initiating and coordinating successive plant response. This study may serve as a rudimentary step toward improving agricultural businesses, as it could inspire new farming practices to increase crop yield. Research published in the Journal of Integrative Agriculture Qin et al. (2020) discovered that sound pressure levels (SPLs), exposure periods, and distance from the sound source all influence plant growth. In that study, the yield of crops such as sweet pepper, cucumber, and tomato significantly increased by 13.2%. Therefore, this bioelectrical communication should be better understood, since this underlies the reported effects of sound on the growth of plants and their production. Acoustic stimulation may also be a potential means for improving plant health, resistance to environmental stress, and performance in controlled-environment farming such as greenhouses, aside from yield enhancement. Theoretical

contributions include developing knowledge in the fields of plant sensory biology and the idea that plants demonstrate sensory and electrical responsiveness, and providing stronger scientific support that plants have sophisticated internal systems.

Literature Review

This literature review is organized using a topical structure and reviews research conducted within the fields of molecular signaling to sound, growth and physiological effects, ecological and defense-associated effects and then research and methodological concerns in electrophysiology of plants. This structure allows for a clear transition from the internal plant mechanism to the observable results and more general research implications. Plant bioelectricity has a significant impact on plant response to its environment. Electrical signals enable plants to perceive and adjust environmental variations and changes in natural light, temperature, and mechanical stimuli (Fromm & Lautner, 2007). More recent studies have shown the impact of sound waves as a type of mechanical vibration that may affect ion movement, growth pattern, and even influence gene expression (Li et al., 2021). These observations have led to emerging scientific interest in plant acoustic perception and its biological importance. Even though multiple studies have addressed the association between different sound frequencies and plant growth, few investigations have been conducted to know the effect of culturally significant sounds, including the Adhan. As a gap remains between the field and human study of auditory stimuli with environmental and community relevance, it is essential to explore how this plant response might occur in response to different types of meaningful auditory stimuli which occur in specific environments or communities.

Plant Acoustic perception and Molecular Signaling

As shown by recent studies, plants seem to respond to sound more than originally thought, and sound could cause changes in biological processes in plants. In one experiment, it was found by Ghosh et al. (2016) that the vibration resulted in a change in the gene and protein expression associated with stress tolerance and hormones in the plant species Arabidopsis thaliana. In yet another experiment conducted by Kim et al. (2021), sounds were noted to cause alterations in the gene expression responsible for the development of plants. Therefore, based on the results of both experiments, sound can be perceived by plants as a stimulus, and not noise.

Growth and Physiological Outcomes of Sound Exposure

Various experiments have been conducted to investigate whether drastic alterations can be made in the growth of plants because of such biological reactions. According to Kim et al. (2021), the roots of plants tend to extend themselves when exposed to low frequencies of sound waves; at the same time, there is increased cellular activity during the growth process. Such results give researchers an idea about the mechanisms behind controlling the hormones and energy levels of plants while growing; they are influenced significantly by sound in many ways. Similarly, according to Gosh et al. (2016), variations in the hormones of plants due to sound exposure tend to happen before any physical changes take place.

Ecological and Defense-Related Vibrational Responses

It is evident that sound affects ecological relations in plants in that they respond to natural vibrations in their own environment. Appel and Cocroft's (2014) study found that plants which

heard caterpillars chewing produced more defensive compounds and demonstrated an ability to sense the threat through vibration. A second kind of response was observed by Veits et al. (2019) which showed that when flowers are exposed to sounds that mimic those made by pollinators, they yield higher quantities of sugar in their nectar. These illustrations suggest the value of vibrational stimuli through which plants use them, not only for their reproduction but also for their survival. These results underscore the importance of the current research project to focus on culturally relevant audio suggesting that they may also respond to specific, significant sounds of common life.

Methodological Challenges and Ongoing Debates

Before the present study, it was shown that plants utilize electric signals to communicate between internal cells and to respond to environmental change like light, touch, and vibrations. Fromm and Lautner (2007) first demonstrated the functionality of this bioelectrical signaling that allows the plants to communicate, react and respond to environmental factors like mechanical touch and vibration. Additionally, new studies have found the effects of sound waves and vibrational input on membrane ion transport and the resulting changes in surface electrical potentials propagated in plant tissues (Li et al., 2021). These bioelectrical signals have now been identified as rapid communication channels for environmental signal transmission beyond the immediate level of stimulation. Additionally, Madariaga et al. (2024) collected an electrophysiological dataset that includes a spectrum of plant species from which predictable electrical responses to specific stimuli can be compared, indicating that plants can generate predictable electrical patterns upon exposure to these various types of stimuli. Taken together,

earlier studies indicate how sound may impact plant bioelectrical activity in discernible manners. This indicates that the observed electrical responses aid in explaining plant responses to different types of sound exposure.

Methodology

This chapter explains the methodology used to study how sound affected plant growth and bioelectrical activity. Building on the ideas and studies discussed in earlier chapters, the research

looked at whether different sounds, including the Islamic Adhan, Violin Sonata by Johann Sebastian Bach, and ambient outdoor sounds, could trigger changes in basil plants. While previous research has shown that plants can respond to sound and vibrations in ways that influence their development, including triggering internal signaling pathways in response to acoustic stimuli (Melo, 2023), this study applied an experimental approach to observe these effects directly. The chapter outlines the research problem, the type of research conducted, and the method used to understand how the plants' growth and electrical responses were observed and compared.

Evaluating Validity

Among other aspects related to this topic, one can mention the influence of different sounds, including Islamic Adhan, Johann Sebastian Bach's violin sonata, and environmental sounds on plant growth and their bioelectrical processes. To resolve this problem, the combination of qualitative and quantitative approaches, including primary data analysis, was employed. Different approaches based on experiments were used during this study. One of the most crucial aspects of the experiment method was connected with the distribution of basil plants into three separate groups. All three groups consisted of five basil plants each. It is important to note that while all three groups shared the same baseline ambient sounds, the experimental groups were separately and additionally exposed to either the Adhan or the violin sonata. Consequently, the employment of the experimental method was designed for the investigation of the effects of different sounds on the growth of the mentioned plants.

Experimental Design and Procedure

Data was collected with a controlled repeated-measures experimental design in order to examine the effect of auditory stimuli on the growth and electrophysiological activity of *Ocimum basilicum* (common basil) over a period of nine days. This species was selected because it grows rapidly and it can also be grown easily and used widely in daily life in the United Arab Emirates. Fifteen healthy plants of similar size were commercially sourced from a local retailer (Carrefour, UAE) and assigned to three experimental groups (n = 5 per group). All plants were raised outdoors under natural environmental conditions characteristic of April, such as sunlight and temperature exposure and background environmental sound. Because control of the outdoor environment was not possible, the focus was on maintaining the same soil composition, watering program, and overall plant care. The ambient sound group was presented with only natural environmental noise and was used as reference control. Sound input was deliberately regulated. Audio stimuli were provided through a speaker at a distance of 20 cm from each plant with a sound intensity of 60 decibels, with decibel level confirmed using a decibel-measuring application. The groups were also spaced apart to prevent sounds from one condition from influencing another. All plants were exposed to their auditory condition for 15 minutes per day, during early afternoon hours when plants are most bioelectrically active. On day 0, initial measurements were taken to establish a baseline. At this stage, no auditory stimuli were applied. The SpikerBox was connected to the plants to ensure they were bioelectrically stable with no existing fluctuations, and the initial length of the smallest leaf on each plant was recorded. Data collection then continued through the measurement of this specific smallest leaf from each pot. Electrophysiological activity and physical growth were the two major data sources for data collection purposes. Electrical activity was collected with the Plant SpikerBox, by wrapping the

wire around the main stem, which was the strongest and tallest part of each plant; this box shows the voltage fluctuations from the plant's internal signaling. The development of the subject was assessed on a daily basis based on the same smallest leaf. The measurements of the length of the leaf were conducted every three days during the whole period of experiment by using a measuring tape and compiling results into the table. The measurement period began with the very start of the experiment (day 0) and ended with its end (day 9). The auditory stimulus is known as the independent variable while electrophysiological response and growth are dependent variables. The control variables are the intensity of sound (60 dB), distance from the sound source (20 cm), time and duration of sound effect, and the standards required to provide growth. It should be noted that the main aim of the experiment was providing the equal conditions for both types of sounds to be able to distinguish the influence of one or another.

Data Analysis Method

The gathered data was analyzed using a mixed-methods approach. The bioelectric signals of the plants were recorded using a Plant SpikerBox (Backyard Brains, n.d.). The data was organized according to the varying sound conditions tested, including a control condition with ambient outdoor sounds, exposure to Adhan, and Johann Sebastian Bach's violin sonata. Recordings from each condition were grouped and labeled to allow for accurate comparison across trials.

For the quantitative analysis, physical growth was tracked by measuring the length of the smallest leaf on each plant every three days (Day 0, 3, 6, and 9). These individual measurements were recorded directly into a table to show the exact growth progress of each plant over time.

For the qualitative analysis, the patterns of the bioelectric signal were closely observed and evaluated for recurring trends and responses regarding the different sound conditions. This included evaluating whether certain responses were consistently increasing, decreasing, or otherwise regarding electrical activity. This was done by observing the responses across multiple trials to get a better understanding of the reliability of the responses. This was then used as a way of getting a more complete understanding of the responses with regard to the different sound stimuli.

Overall, the use of quantitative and qualitative analysis in this study ensured that the plant's bioelectric responses under varying acoustic inputs were examined in detail. The objective evaluation and interpretation of the numerical characteristics of the signal were ensured through the analysis and identification of patterns in the signal's behavior. Together, these approaches created a strong foundation for understanding how specific types of sound may influence the bioelectrically activity of plants.

Justification of Methodology

In our research, it became evident that using both quantitative and qualitative experimental approaches proved to be useful since it enabled us to directly assess the bioelectrical response of the basil plant to different sound stimuli. These were the Islamic Adhan, the violin sonata by

Johann Sebastian Bach, and the control sample of the sounds of nature. The fact that all plants were maintained under the same light, water, and temperature conditions ensured the difference in physiological effects due to sound exposure was being captured, rather than environmental alterations. This allowed for the observation of controlled sound exposure compared with ambient natural sound. This made sense because the investigation would be concerned with the measurable changes of a plant, while qualitative research is concerned with the external impact of the stimulus.

Moreover, the experiment also considered the effect of distance from the sound source (about 20 centimeters), types of plants, decibel levels (about 60 decibels), and general environment, thus reinforcing the validity for the study. Simultaneously, performing the experiment in a green backyard setting adds ecological validity. This is because it shows the realistic environmental conditions that plants usually grow in.

The experiment was limited to only five plants per condition, as the equipment was only able to take a few recordings at the same time. Because of this, it was mandatory to conduct multiple measurements over several days. Using this approach, collected information helped in the understanding of how it changes over time and how reliable it is. In contrast, completely qualitative approaches would not recognize subtle electrical changes in sound or no experiment at all. In terms of scientific analysis dealing with plant electrophysiology, it has been demonstrated that on average, electrical impulses act as consistent predictors of plants' response to environmental changes (Fromm & Lautner, 2007).

However, it is necessary to point out that there are some restrictions on conducting the study via this methodological approach. To begin with, the presence of uncontrollable external factors such as noise from cars and other human activity has made it impossible to conduct a pure

control experiment; therefore, the research design does not appear to be useful for studying the effects of sound as a stand-alone factor. In addition, the device used for recording electrical impulses is relatively insensitive to minor fluctuations. Nonetheless, the described experimental technique may be considered appropriate in the context of comparative investigation.

Conclusion

Overall, the present investigation has been oriented towards the comparison of the influence of various types of auditory stimuli on the growth of *Ocimum basilicum* (common basil). It should be noted in this respect that the aim of the experiment was to explore whether there were any differences in plant reactions to various stimuli in terms of using the experimental method and data analysis with the application of both qualitative and quantitative methods. Due to the appropriate control of the sound stimulus, the amount of lighting and watering, the reliability of the research has been raised and thus, there was no danger of moving away from the theme and exploring some other issue since the topic itself was concerned with the effect of certain stimuli. Nonetheless, despite the highly structured approach, the research on electrophysiological processes in plants cannot be regarded as a closed system due to external factors.

Findings and Discussion

Data Overview and Experimental Setup Recap

Physiological behavior and growth behavior of *Ocimum basilicum* under sound wave stimuli have been examined in this study. In the present experiment, auditory stimuli have served

as independent variables. Auditory stimuli used in the current experiment include Islamic Adhan, musical notes created by the composer Johann Sebastian Bach in 432 Hz frequency, and natural outdoor sounds as control. Assessment of growth behaviors of the plant has been carried out through alterations in signal pathways of plant growth and plant growth itself. Changes in leaf lengths of the plant and assessment of growth through Spiker box machine have been employed in this regard.

In the current experiment, fifteen *Ocimum basilicum* plants have been used. Each group of the plant has been provided with distinct types of sound. The sound was delivered 15 minutes per day over a period of nine days.

This means that the environment where all samples grew had been equal for each of them, meaning that such factors as the quantity of light, soil conditions, and watering had been equal. The sound was kept at the intensity of around 60 decibels for each group of plants. The speakers, which produced sounds, were located at the fixed distance of 20 centimeters from basil plants' samples. Thus, this ensured the identical acoustic perception of sound stimuli for all plants. The control group, which did not have any impact of sounds but the outdoor noises only, served for comparison with experimental groups.

Electrical activity of the plants was measured by using an electronic device named Plant SpikerBox during the period when the sound effect on plants was performed. Growth of plants was estimated by means of studying changes in the appearance of the leaves every three days. The same leaves were studied throughout the entire experiment.

In general, it may be stated that the described experimental set-up helped to obtain data concerning the reactions and electricity generation by the basil plants under similar

environmental conditions. Under the conditions of stable external environment and sound effect influence, it became possible to relate certain reactions of the plants to the influence of particular sound stimuli used. Baseline bioelectricity values were measured before application of the sound effect; they are shown on Figure 1.

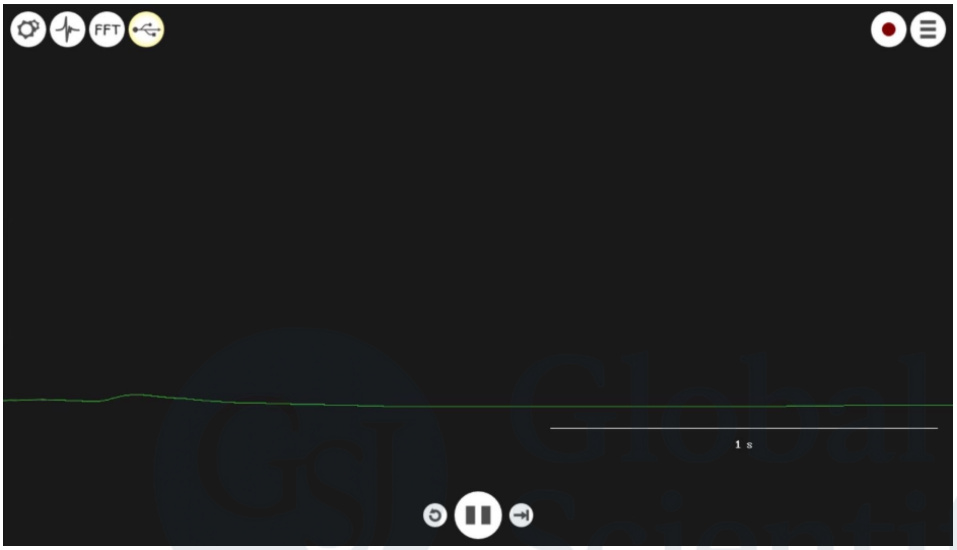

Figure 1. Bioelectric activity of basil plants prior to sound exposure

Effect of the Islamic Adhan on the Bioelectric Activity of Basil Plants

In this section, the effect of the Islamic Adhan on the bioelectric behavior of basil plants will be explored and analyzed. Bioelectric readings were collected before and while being exposed to Adhan in order to compare the results when there is no stimulus applied with the results when an auditory stimulus is applied.

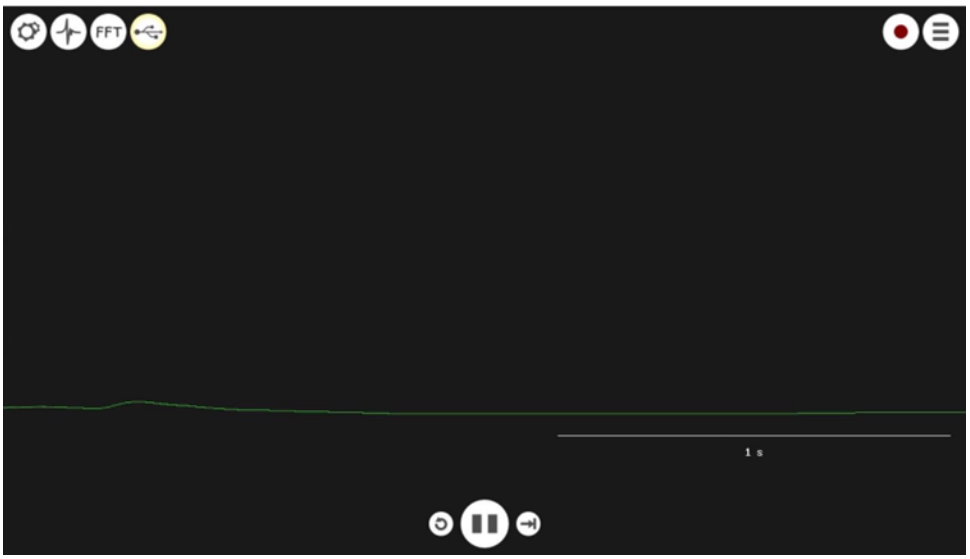

Figure 2. Bioelectric activity of basil plants before exposure to the Islamic Adhan.

The analysis of bioelectrical signals prior to, during, and for 30 seconds after exposing to the sound waves of Islamic Adhan proves that there are some differences in the electrical activity of the plant. Prior to exposing the plant to the sounds of Adhan, the signals were relatively stable with some fluctuations and low amplitude. Thus, it could be stated that the plant emitted bioelectrical energy in a constant way since no stimuli affected it.

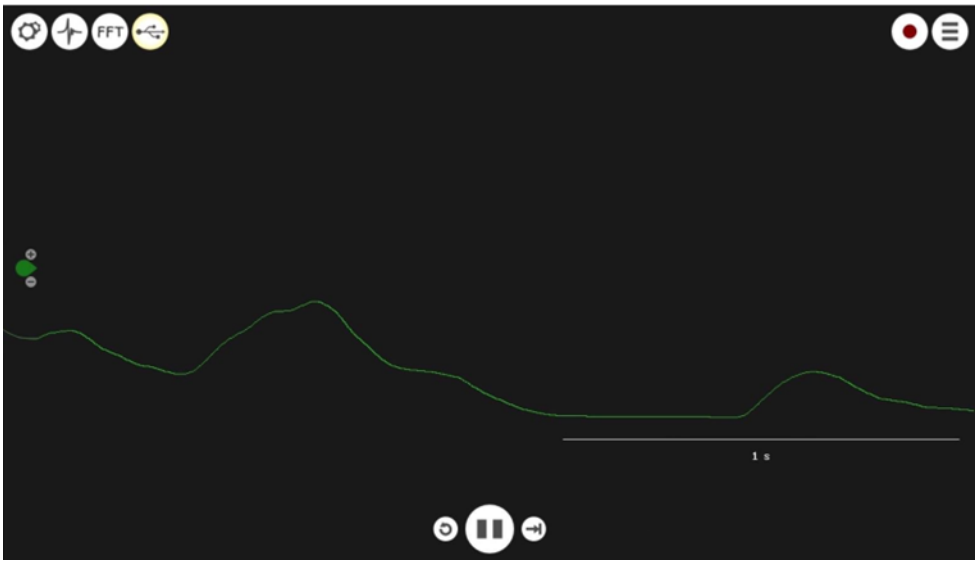

Figure 3. Bioelectric activity of basil plants during exposure to the Islamic Adhan for 13 minutes

When the plant was exposed to the sounds of Islamic Adhan, its electrical signals became less stable; that is, the amplitude increased. It can also be seen that the wave shape has changed due to its increase in amplitude; therefore, it can be said that the electrical activity of the plant intensified when reacting on the stimuli.

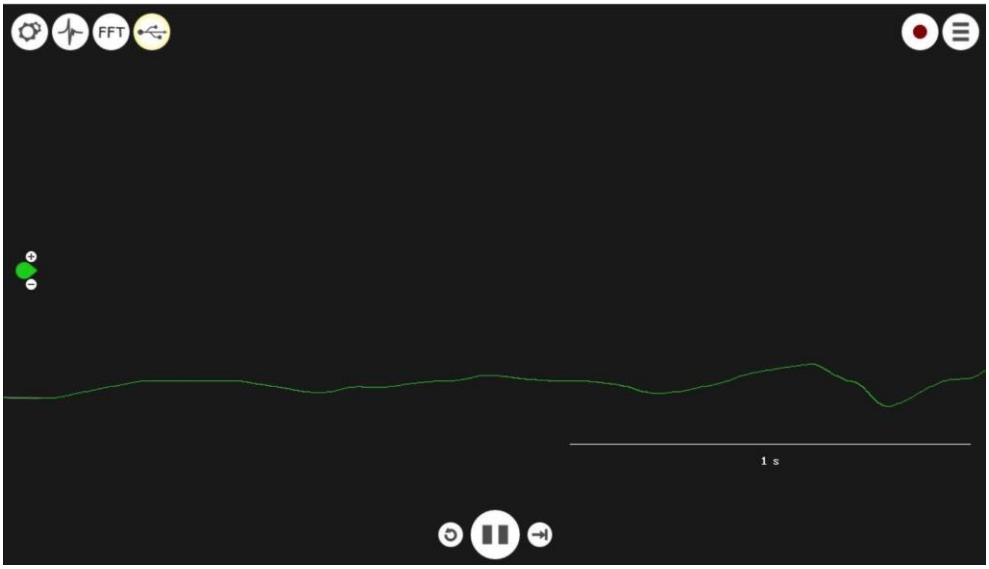

Figure 4. Bioelectric activity of basil plants 30 seconds after being exposed to Islamic Adhan

During the next thirty seconds after the sounding of the Islamic Adhan, the bioelectrical wave still exhibited slight fluctuations in amplitude. Despite the alterations in the wave since the initial wave seen when the plants were directly exposed to sound waves, the effects persisted even after withdrawing the sounds as stimuli. It thus illustrates that even after the removal of stimuli, temporary effects exist in plants.

Analysis

It could be concluded that this experiment proved that the Islamic Adhan had an influence on the biological electric processes within the basil plant, in terms of increased electrical activity within it. The fact that electrical activity could still be detected after 30 seconds shows that plants can react to sounds using biological electric processes. While minor discrepancies may have occurred because of external factors, what matters most here is that a significant difference was indeed observed between the two sets of results.

Effects of The Violin Sonata on The Bioelectrical Activity of Basil Plants

The following chapter discusses the outcomes and interpretations of the experiment that was conducted to explore the effects of different audio signals on the physiological and bioelectrical reactions of *Ocimum basilicum* (common basil). The findings from the experiment, where the recordings and growth of the plants were observed using a Plant SpikerBox, are presented below.

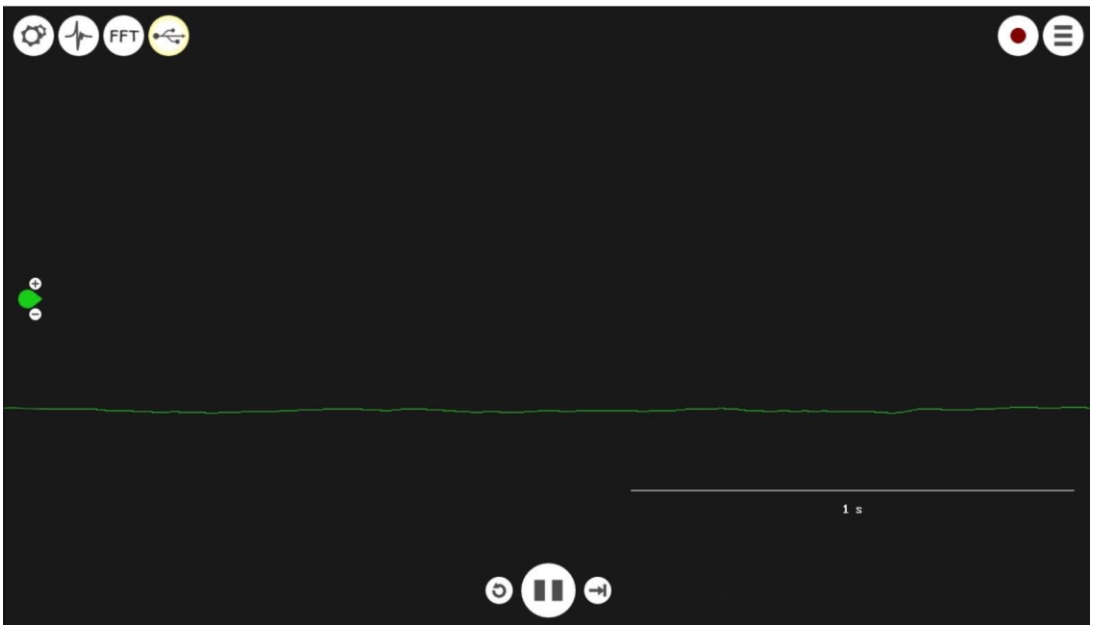

Figure 5. Bioelectric activity of basil plants before being exposed to Violin Sonata

From the graph displaying the electric signals emitted by the basil plant before exposure to the sounds of a violin sonata, it is evident that there was stability and a lower rate of fluctuation for most of the time period under observation. In this case, the basil plant maintained its stability and had less stimulation by the environment around it. This helps provide a useful benchmark against which to compare future readings while under influence of the sounds being played. In terms of the research question posed in the study, these results show that if there was to be higher levels of electrical activity, then this was due more to the sounds of the sonata rather than background electrical activity.

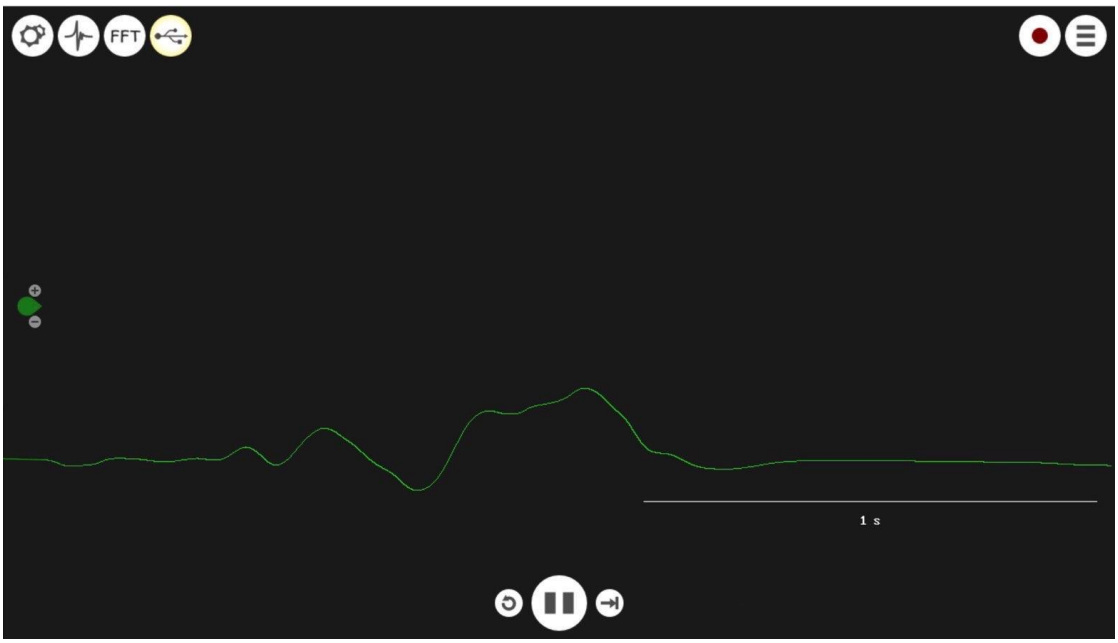

Figure 6. Bioelectric activity of basil plants initially after exposure to the Violin Sonata for 13 minutes

The violin sonata had an effect on the basil plant. This is seen in the basil plants' response. The graph in Figure 6 represents the reaction of the basil plant when it initially recognized the violin sonata. The exposure of the basil plant to the sound resulted in several fluctuations in the signals of the plant. Peaks and drops were observed, and the signal had a stronger increase near the midpoint of the recording. This indicates that the basil plant reacted instantly to the violin sonata, suggesting the sound waves from the violin sonata were a new stimulus in the environment that the basil plant detected. These observations support prior research on plants responding to vibrations due to changes in internal signaling (Fromm & Lautner 2007).

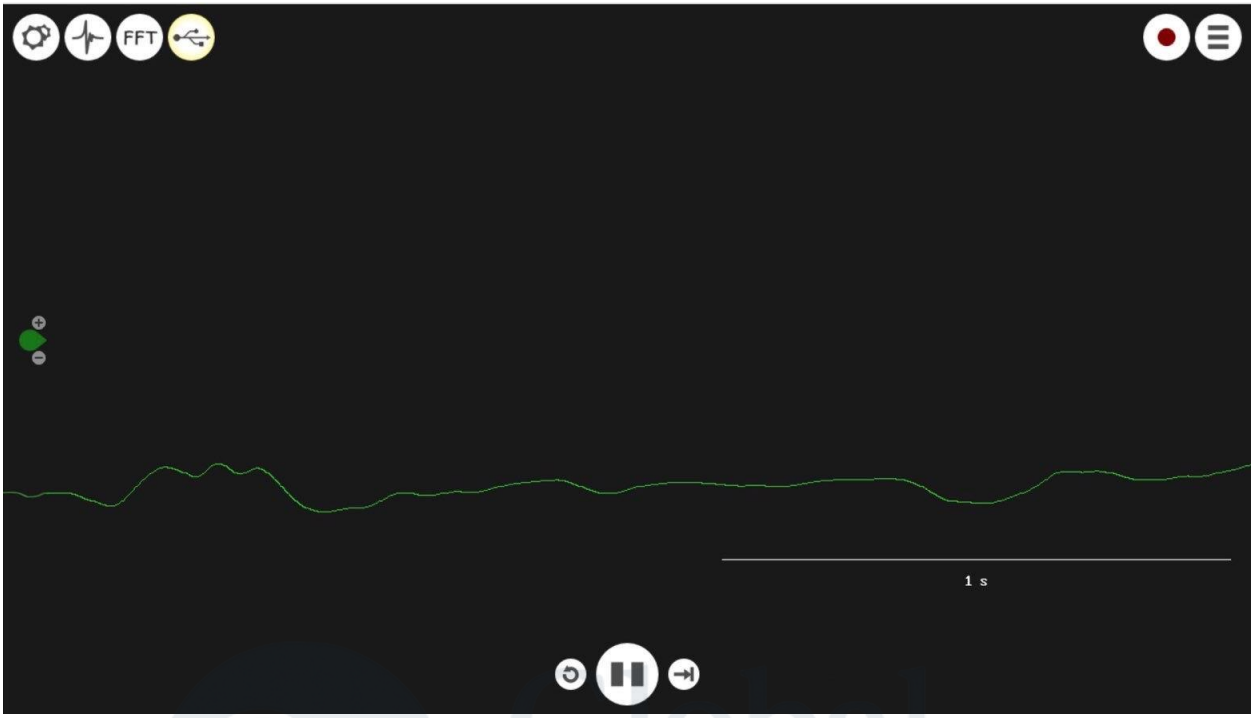

Figure 7. Bioelectric activity of basil plants 30 seconds after stopping exposure to the Violin Sonata

The bioelectric activity of the basil plant thirty seconds after its exposure to the violin sonata exhibited more noticeable oscillations compared to the original electrical activity that was produced before the introduction of sound vibrations. As shown in the graph presented above, the bioelectric activity underwent multiple peaks of rises and falls, especially during the first few and last seconds of the data collection period, thus indicating greater electrical activity in the plant. In contrast to the almost stable electrical activity exhibited at the beginning, there appears to be greater responsiveness following the exposure to sound vibrations. It may be concluded from the findings that the sound vibrations of the violin sonata were capable of stimulating electrical activity in the basil plant.

Analysis

Overall, taking into account the results of the graphs drawn from the data collected prior, during, and after the sound stimuli were applied to the basil plants, it could be concluded that certain changes took place in terms of the bioelectrical activity of the basil due to the influence of the sound. The graphs demonstrated that there were no numerous fluctuations observed before the application of the sound stimuli, meaning that the basil plants were at rest. Nevertheless, once the plants were affected by the sounds, they began showing high-frequency changes, which implies that the plants responded to the stimuli instantly. Even after thirty seconds of sound exposition, the fluctuations continued being seen; however, they were much less volatile than those during the exposure period.

Effect of Sound Conditions on Basil Leaf Growth

This section discusses and evaluates how various sound environments impact the physical development of basil plants. Leaf length data was collected over nine days for plants subjected to the Islamic Adhan, violin music at 432 Hz, and natural outdoor sounds. The information was analyzed to uncover variations in growth trends and general plant progress among the three experimental groups.

Figure 8. Data of the growth of basil leaves (cm)

Basil Leaf Growth Data (cm)

Plant	Group	Day 0	Day 3	Day 6	Day 9	net change
Plant 1	Athan	0.88	1.46	2.14	2.93	+2.05
Plant 2	Athan	0.81	1.33	1.94	2.76	+1.95
Plant 3	Athan	1.07	1.71	2.52	3.35	+2.28
Plant 4	Athan	0.95	1.41	1.20(wilted)	0.82(shriveled)	-0.13
Plant 5	Athan	1.03	1.63	2.47	3.18	+2.15
Plant 6	Violin (432 Hz)	0.86	1.37	2.04	2.91	2.05
Plant 7	Violin (432 Hz)	0.94	1.50	2.25	3.08	2.14
Plant 8	Violin (432 Hz)	1.05	1.67	2.55	3.31	+2.26
Plant 9	Violin (432 Hz)	0.91	1.44	2.19	3.02	+2.02
Plant 10	Violin (432 Hz)	1.12	1.62	1.56(drying)	1.34 (wilted)	+0.22
Plant 11	Ambient noise	0.89	1.28	1.50	2.44	+1.55
Plant 12	Ambient noise	0.92	1.34	1.60	2.56	+1.64
Plant 13	Ambient noise	1.01	1.45	2.06	2.74	+1.73
Plant 14	Ambient noise	0.85	1.11	0.95 (stall)	1.16	+0.31
Plant 15	Ambient noise	0.97	1.38	1.98	2.62	+1.65

Analysis

The results indicate that all basil plants were growing within the experimental period regardless of the different levels of growth due to the sounds used. The level of growth for basil plants in the Adhan sound treatment occurred nine days from Day 0 up to Day 9. As an illustration, Plant 3 began at 1.07 cm and grew to 3.35 cm, which is a total of +2.28 cm. Additionally, Plant 5 began at 1.03 cm and reached 3.18 cm, which is a total of +2.15 cm. A

basil plant that was exposed to the Athan sound experienced wilting and shriveling, which has a negative net growth rate of -0.13 cm.

Plants played with the Violin Sonata having a frequency of 432 Hz had a better growth than those in the other two categories. The growth of the length of the leaf of plants in the violin category was faster during all experiments. Growth of length of Plant 8 was 1.05 cm on day zero to 3.31 cm on day nine, which amounts to a net growth of +2.26 cm. Similar was the case with plants 7 (0.94 cm to 3.08 cm) and plant 6 (0.86 cm to 2.91 cm). Though there was some dehydration in Plant 10, the result of plants in the violin category was better.

On the other hand, the plants that were exposed to the environmental sounds outdoors demonstrated a rather slow and inconsistent growth pattern in comparison to others. Even though there were some plants that were growing consistently, the net increase in their size was still comparatively low than that of the other plants. As an example, even though Plant 13 increased its size from 1.01 cm to 2.74 cm (a net increase of +1.73 cm), Plant 14 stopped growing by the sixth day and resulted in a net increase of only +0.31 cm. It is evident that well-organized sound stimulation such as Athan and Violin had a higher effect than mere environmental sounds.

Overview of findings

The results of this chapter demonstrate that various sounds significantly influenced the activity and growth of *Ocimum basilicium,* commonly known as basil plants. In this study, Plant SpikerBox device was employed to determine the leaf lengths in order to examine the reaction of plants to the Islamic Adhan, Violin Sonata (432Hz) and ambient environmental sounds. It can be seen that various sounds caused different reactions among plants. For instance, when exposed to the Islamic Adhan, the results showed that there was increased electrical activity in plants compared to those without any sound exposure. There was an increase in electrical activity of the plants exposed to violin sounds, but this later on decreased indicating that plants have adapted to the sounds. The plants exposed to the sounds of violin matured within nine days. On the other hand, plants exposed to the Islamic Adhan showed growth at a steady pace, while plants exposed to natural sounds had slow growth. This chapter explores the effect of sound on the physiology and development of herb basil. Different sounds have been used to investigate the resultant changes in behavior and growth of plants, and the results discussed in the light of current knowledge relating to basil. The findings are then used as a basis for making some practical recommendations for the use of sound in the cultivation of this versatile herb.

Conclusion

This chapter is an overview of the main results obtained in relation to the effect of different sounds on the growth and bioelectrical activities of basil plants. In particular, the study was concerned with investigating the effect of the Islamic Adhan, violin music set at 432 Hz, and general outdoor noises on plants. The main goal was to investigate whether there is any connection between sound and plant physiological processes. This chapter provides a review of the overall results of the study in relation to the original hypotheses.

Summary of Findings

Based on the results of this study, it can be stated that auditory stimuli can affect the bioelectrical and physiological growth of basil plants. The experiments have shown that there were significant differences in the bioelectrical activity of basil plants exposed to different auditory stimuli like the Islamic Adhan, 432 Hz violin music, and ambient outdoor noise.

During the bioelectrical activity recordings, it was found that basil plants exposed to the Islamic Adhan had higher electrical activity than the control ones recorded prior to the experiment. During the sound exposure process, there were significant fluctuations in the wave pattern, which indicated an active reaction of the plants to the auditory stimulus by means of their bioelectrical activity. Basil plants exposed to violin music also exhibited an increase in their electrical activity, especially at the beginning of sound exposure. Nevertheless, it was observed that basil plants retained their responsiveness to the auditory stimuli.

In addition to these observations, the measures of physical growth taken on all the plants during the experiment were different from each other depending on the type of sound. Of all three groups, the plants subjected to the sound of violin had the highest total growth regarding leaf length within the observation period. The same is true for the plants subjected to Islamic Adhan except one plant which wilted during the experiments. However, plants exposed to natural noises were slower in their growth.

On the whole, it can be stated that the data obtained proves the thesis formulated in the hypothesis as well. As for comparison, both types of sound had a greater effect on plants than the sounds of the environment. It corresponds to previous research which has shown that plants can react to various external influences.

Implications of The Study

Firstly, the results of the study will help to enhance the knowledge base of plant electrophysiology in general since the study shows that basil plants are able to demonstrate different bioelectrical activity depending on the type of auditory stimulus applied: Islamic Adhan, violin sonata music, and the ambient noise of the surrounding environment. This finding is consistent with the findings of earlier studies that indicate that plants may be capable of responding to mechanical oscillations caused by sound vibrations (Fromm & Lautner, 2007). Another implication of the study may consist in its usefulness for advancing sustainable agriculture. Should it prove beneficial for plant development, exposure to sound waves can be employed as one of the means to promote healthy plant growth and development. Moreover, the

findings of the experiment may increase the current scientific knowledge about plant sensory systems by proving the presence of certain physiological reactions to culturally and/or musically different sounds.

Moreover, the study has regional importance in the sense that there have not been many experiments dedicated to plant bioelectricity conducted in Middle Eastern environmental conditions. Through conducting the experiments in the United Arab Emirates under the conditions of natural environmental exposure common for the region, the study offers initial data regarding the potential application of sound-related plant studies in the local climatic environment.

Thirdly, the use of the Adhan in Islam as a sound stimulus offers the opportunity to explore a cultural aspect of this phenomenon, which was seldom considered in past scientific studies.

Lastly, the results of the present research might stimulate subsequent studies on the interrelation between sound vibration and plant physiology and behavior. In the future, other plant types and music genres, as well as sound frequency ranges and duration of exposure to acoustic stimuli, can be analyzed.

Delimitations of The Study

The study was restricted to the effects of three types of auditory stimulations, which include the Islamic Adhan, violin sonata of Johann Sebastian Bach, at a frequency of 432 Hz, and ambient noises of the natural environment. Thus, the results are solely relevant for particular sounds tested in the experimental conditions. The research was performed with a specific plant species “Ocimum basilicum”, commonly known as basil. The plant species selected was based on fast

growth and availability in the United Arab Emirates. Thus, the results can be generalized to all other plant species.

However, the experiment was carried out in natural environmental conditions in April and certain variables such as soil content, sound volume, distance from the speaker, and exposure period were controlled, but other external variables like wind, sounds outdoors, and changing temperatures could not be controlled. As such, it was not possible to perform the experiment in an isolated laboratory. Furthermore, since the study used solely five plants for each of the three conditions, the number of experimental subjects is significantly small, and this was caused by restrictions in equipment and access to Plant SpikerBox. Moreover, the results depended on the sensitivity of the measuring tool, so slight variations in bioelectric activity may not have been captured. The study was also limited in terms of the period, lasting for about three or four weeks.

Further Research

The effect of sound vibrations on the bioelectrical activity of Ocimum basilicium is one major outcome of this experiment whose purpose is to determine the electrical variations in living systems caused by sound vibrations. It means changes in potential and ionic current variations caused by stimulation with sound. Further research needs to be conducted to validate and develop the findings obtained here. Many specimens and wide variety in their selection should be considered in further research since they allow determining the sound response between species. This research demonstrates the fact that plants respond to sounds. This is shown in the paper "Towards Understanding Plant Bioacoustics" written by Gagliano, Mancuso, and

Robert in 2012. Consequently, further experiments may be conducted with other types of plant species to determine their reaction.

In carrying out the experiment in the UAE, the research environment has unique characteristics, such as heat, intense sun, and high humidity, which could have affected plant growth and their response to sound stimuli. While the current results have been achieved because of the presence of such environmental factors, an experiment carried out under different environmental conditions could lead to a totally different result due to the effect of the environment on plant response to sound stimuli. Experiment comparison under different environmental conditions is one of the ways used to identify how climate factors interact with sound stimuli. Experiments will also be conducted in a laboratory environment in the future. Despite the efforts by the experiment to make the variables such as the time of watering, level of sound, and process time uniform, some of the variables could not be controlled and could have affected the outcome, such as noise from traffic, wind, rainfall, and temperature variations. This assertion was made by Fromm and Lautner in their article Electrical Signals and Their Physiological Significance in Plants (2007). Thus, future studies may be performed indoors to minimize environmental interferences and to increase the reliability and validity of data, so that sound would be the only element affecting the target plants.

These considerations also make an analysis of a broader range of sound stimuli in future studies both mandatory and evident, which includes frequencies in the spectrum, musical genres, rhythmic patterns, spoken language, and duration of exposure. The study of Growth and

Physiological Responses of Plants to Sound Vibration Treatment by Kim et al. (2021) demonstrated that plant responses vary according to the characteristics of the sounds to which they are subjected. Comparative analyses of classical music and natural environmental sounds and spoken language and culturally significant sounds may facilitate a deeper understanding of the processes by which sound influences plant communication and internal signaling. Research into sound waves of cultural or environmental relevance might help gain insight into the responses of plants in diverse geographical locations or populations.

Experiments might also be conducted to determine whether constant exposure to sound waves would influence the amount of time taken by plants to flower, the weight created, and replication. According to the article Render a Sound Dose: Effects of Implementation of Acoustic Frequencies on Plants' Physiology, Biochemistry and Genetic Composition, sound stimulation may boost agricultural production; thus, future research might consider exploring ways in which sound stimulation would aid agriculture productivity. Experimentation in greenhouse agriculture and hydroponics would enable determination of whether sound stimulation would be a viable means of boosting agriculture productivity.

Conclusion

In summary, the experiment proved that different kinds of sounds could influence not only bioelectricity but also the physical growth of basil. It has been shown that sounds that are arranged, such as the Islamic Adhan and Violin Sonata at 432 Hz, had greater influence on physical and electrical processes compared to unarranged sounds like the sound of an outdoor environment. The plants exposed to arranged sounds were more energetic in relation to bioelectricity and were physically bigger, thus demonstrating the fact that plants can respond to sounds. Despite difficulties connected with weather and the number of plants used in the experiment, important results concerning the relationship between sound vibrations and plants' physiology have been found out.

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