sustainability

Article

Effect of Audio Control Technology on Lettuce Growth

Su Wang [1] and Qingqing Xiao [2,*]

[1] College of Art, Anhui University, Hefei 230601, China
[2] School of Biology, Food and Environment, Hefei University, Hefei 230601, China
* Correspondence: xiaoqq@hfuu.edu.cn

Abstract: The excessive use of pesticides and fertilizers reduces the quality of crops, harms human health, and causes environmental pollution, thus hindering the sustainable development of agriculture. In the process of realizing ecological agricultural production, audio control technology has increasingly become an area of concern. As a physical agricultural technology, it has become a combination of music acoustics and agricultural science. However, the research on the ecological role and function of audio control technology is still relatively lacking. In view of this, the authors studied the effects of audio control technology (specific frequency sound wave and different types of music) on the growth of lettuce, and showed that the specific frequency sound wave treatment produced by the plant acoustic frequency technology generator significantly increased the growth of lettuce compared with the condition of silent environment processing. Treatments of different types of music (electronic music, rock music, and classical music) promoted lettuce growth, especially the significant increase in the output of edible parts under the influence of electronic music. The research results further showed that the specific frequency sound wave treatment produced by the plant acoustic frequency technology generator enhanced the chlorophyll content of lettuce leaves (1.98 ± 0.15 mg/g), thus promoting photosynthesis. Different types of music had different effects on the photosynthesis of lettuce leaves; electronic music treatment increased the chlorophyll content of lettuce (1.48 ± 0.07 mg/g), and had the greatest impact.

Keywords: audio control technology; music acoustics; physical agriculture; ecological agriculture; sustainable development

Citation: Wang, S.; Xiao, Q. Effect of Audio Control Technology on Lettuce Growth. *Sustainability* **2023**, *15*, 2776. https://doi.org/10.3390/su15032776

Academic Editor: Georgios Koubouris

Received: 31 December 2022
Revised: 28 January 2023
Accepted: 31 January 2023
Published: 3 February 2023

1. Introduction

The development of agricultural science and technology is accelerating year by year and shows diversified characteristics. At the same time, environmental pollution, ecological degradation, and other problems have emerged. In the process of agricultural development, chemical agriculture has greatly improved the output of crops. However, the excessive use of pesticides and fertilizers has reduced the quality of agricultural crops, harmed human health, and caused environmental pollution, thereby hindering the sustainable development of agriculture [1]. Currently, the world's agriculture is transitioning from chemical agriculture to ecological agriculture, making agriculture develop more sustainably. Ecological agriculture follows the principles of ecology and economics, which can obtain higher economic, ecological, and social benefits by comprehensively utilizing the effective experience of traditional agriculture, modern scientific and technological achievements, and management methods. Its core requirement is to coordinate the contradiction between development and the environment, and resource utilization and protection, form the unity of two virtuous cycles of ecology and economy, and form the three benefits of an economic ecological society [2]. Physical agriculture is conducive to the protection of the ecological environment to a large extent and is one of the important ways to realize the transformation from chemical agriculture to ecological agriculture. Physical agriculture is a comprehensively integrated agriculture based on the physical principles of water, heat, light, electricity, magnetism, sound, and nuclear power. It is a new agricultural production technology that affects crops by using specific technical methods to achieve the purpose of increasing production, high-quality products, and pest control [1,3–5].

In the process of realizing physical agricultural production, audio control technology has gradually attracted attention and has become a joining point of musical acoustics and agricultural science. Postmodern musicians believe that the sound used in music is no different from the music used in daily life, which has created a new realm of audio control technology. At the same time, experimental audio control technology has developed more rapidly, such as using a single piece of music to represent a scene, copying or reproducing the listener's sense of space and time [6]. Although audio control technology has been widely used, its concept was not proposed until the 1960s. Europe, the United States, Japan, and South Korea take the lead for the research on audio control technology [7–12]. It has the collective research characteristics of the close integration of industry, education, and research, and develops using the integration of functional research, industrial research and ecological research. At present, audio control technology has been applied in various fields to varying degrees, especially in medicine and psychology, which has attracted extensive attention and research [13].

As a special audio technology, audio control technology can have a certain impact on animals and plants in agricultural production, and this functionality has gradually attracted the attention of agricultural production researchers. Regarding animals, some examples have shown the role of audio control technology on animal husbandry. For example, allowing cows to listen to soothing music can moderately promote the endocrine of cows, increase their food intake, and thus produce more milk. In Japan, the United Kingdom, and other countries, scientists have conducted experiments in this area. Turkey's chicken breeders have learned from their breeding experience that when hens listen to sad music (such as the songs of Jose) they lay more eggs of a higher quality, which is popular with consumers [14]. As for plants, in recent years, more and more researchers have been engaged in the research area of the response effects of audio control technology on the morphological and physiological characteristics of plants, and have made the plant acoustic frequency technology for agricultural operations relevant. These results showed that the yield and quality of various agricultural products has been affected to varying degrees under the application of audio control technology [15–21]. However, the research on the ecological role and function of audio control technology is still relatively lacking. Currently, there are few studies on the effect of sound on lettuce growth. In view of the application status of audio control technology in crop production, the authors studied the effects of audio control technology (specific frequency sound wave and different types of music) on the growth of lettuce.

2. Materials and Methods

2.1. Experimental Design

The authors explored the effects of the plant acoustic frequency technology generator (AFT) and different types of music on the growth of a daily edible vegetable, *Lactuca sativa* L. var. *ramosa* Hort. Lettuce is a common leafy vegetable in China. This experiment was conducted in Hefei University in March and April 2021. The sampling rate of the frequency spectrum analysis software GoldWave was 44,100 Hz for the MPEG format of the sound samples, the green and red waveforms represent the left and right channels (Figures 1A, 2A, 3A and 4A), respectively. In order to display the sound more intuitively, we also collected the waveform (Figures 1B, 2B, 3B and 4B), spectrogram (Figures 1C, 2C, 3C and 4C) and spectrum (Figures 1D, 2D, 3D and 4D). At the same time, we measured the difference of the lettuce yield under the influence of audio frequency control technology, and analyzed the causes (mainly on leaf photosynthesis), providing a scientific basis for the large-scale application of audio control technology in lettuce.

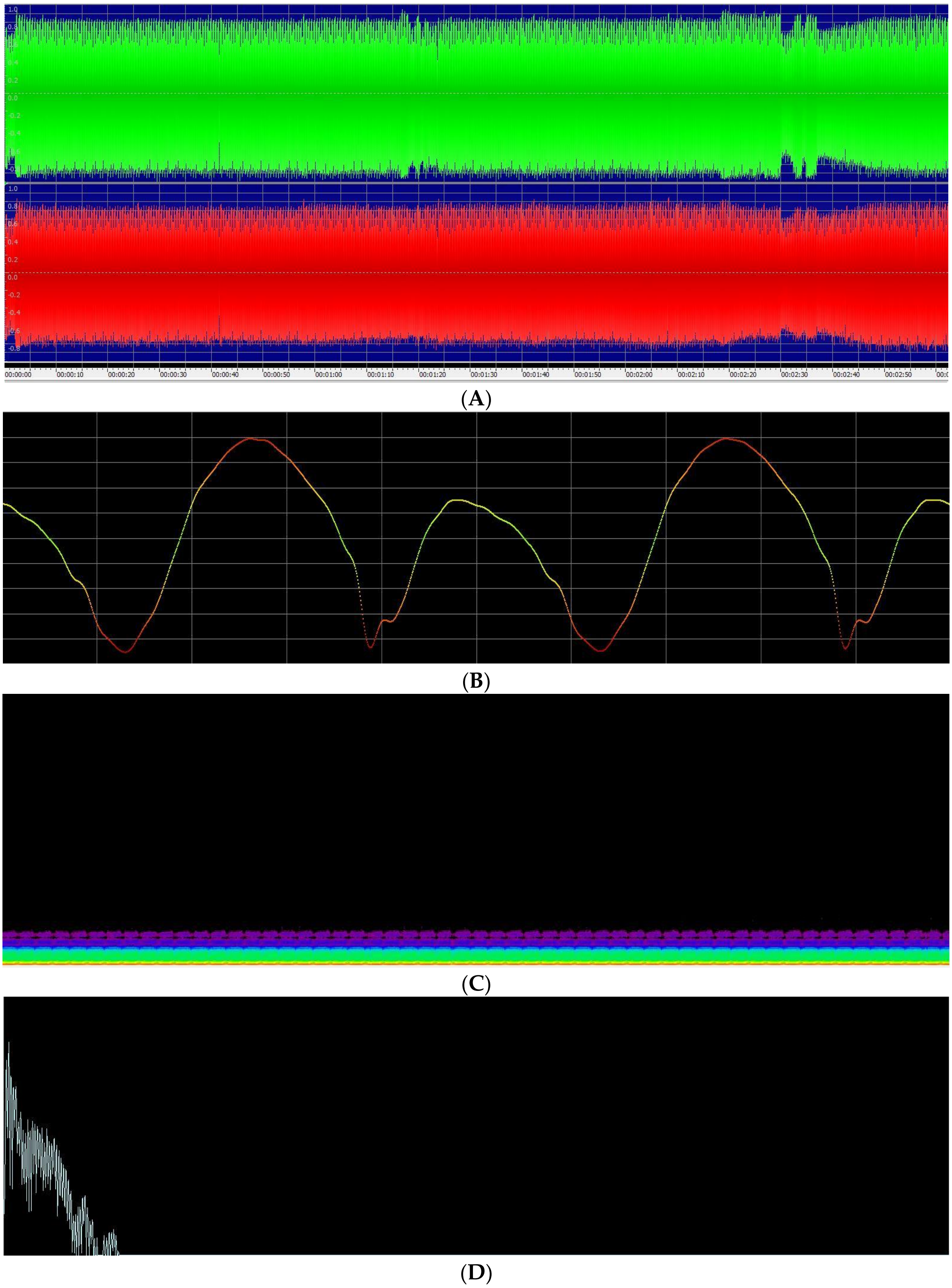


Figure 1. Acoustic characteristic diagram (AFT, specific frequency sound wave, 60 HZ) (**A**: Sound sampling; **B**: Waveform; **C**: Spectrogram; **D**: Spectrum).

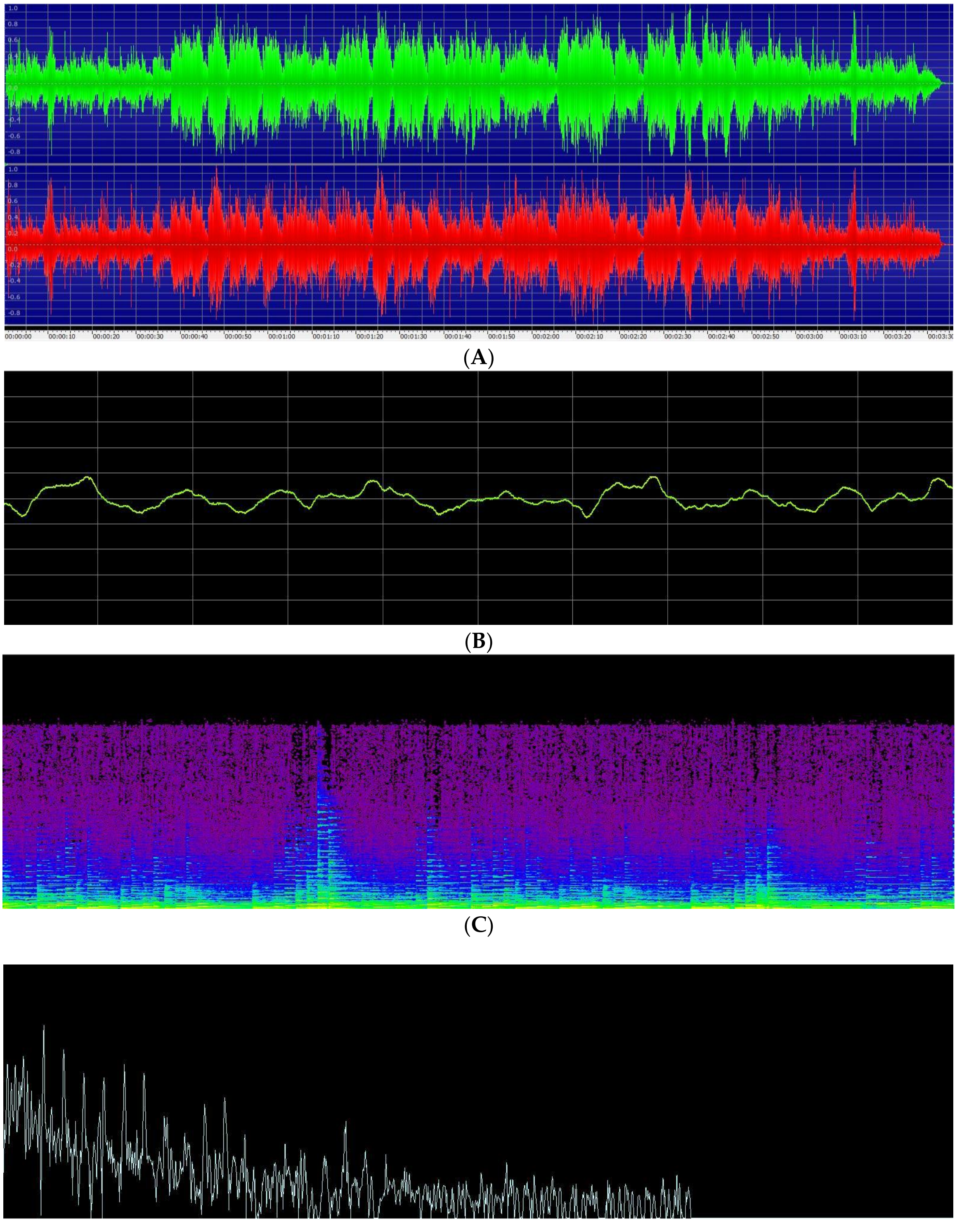
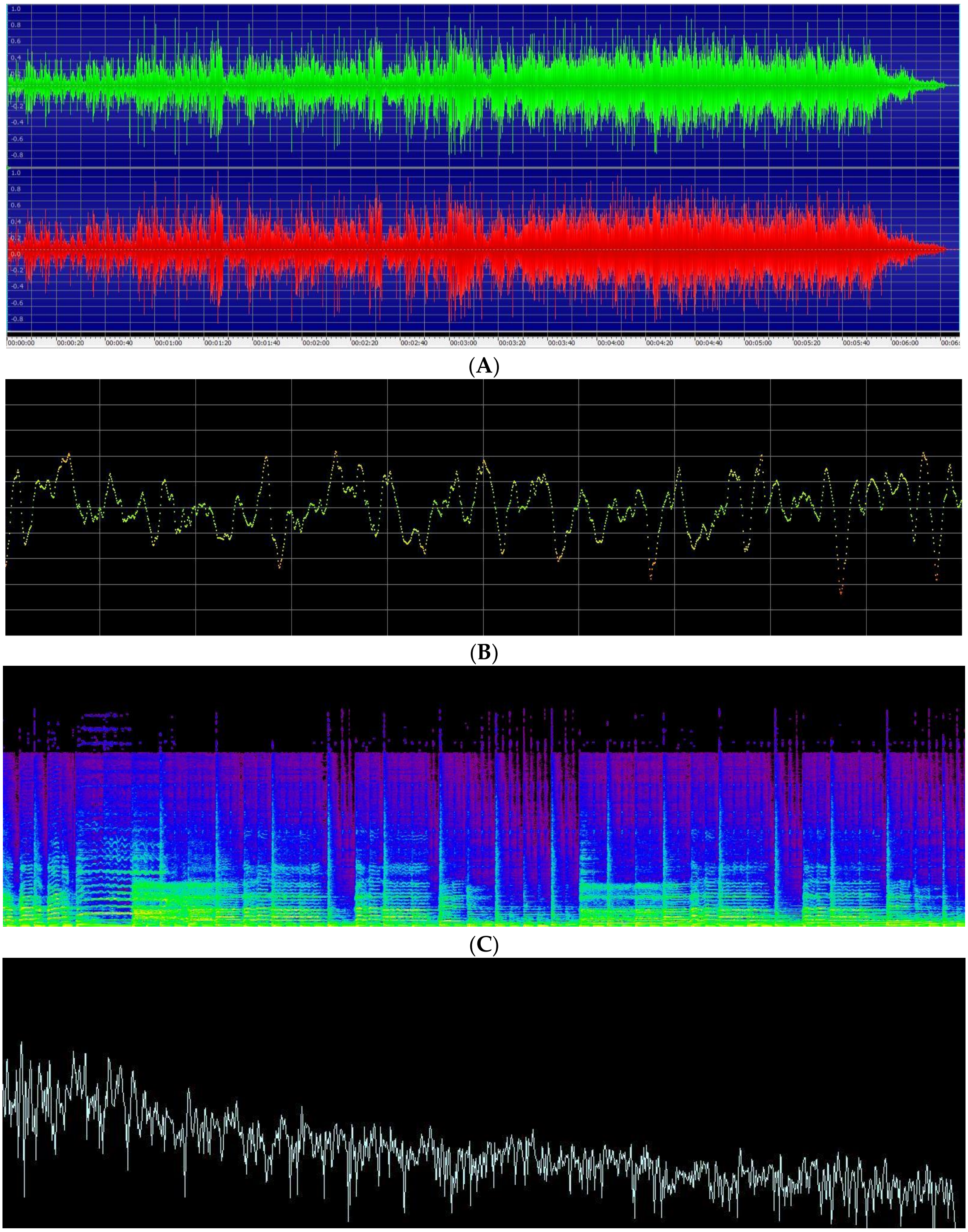


Figure 2. Acoustic characteristic diagram (EM, "Annie's Wonderland") (**A**: Sound sampling; **B**: Waveform; **C**: Spectrogram; **D**: Spectrum).



(**D**)

Figure 3. Acoustic characteristic diagram (RM, "Hey Jude") (**A**: Sound sampling; **B**: Waveform; **C**: Spectrogram; **D**: Spectrum).

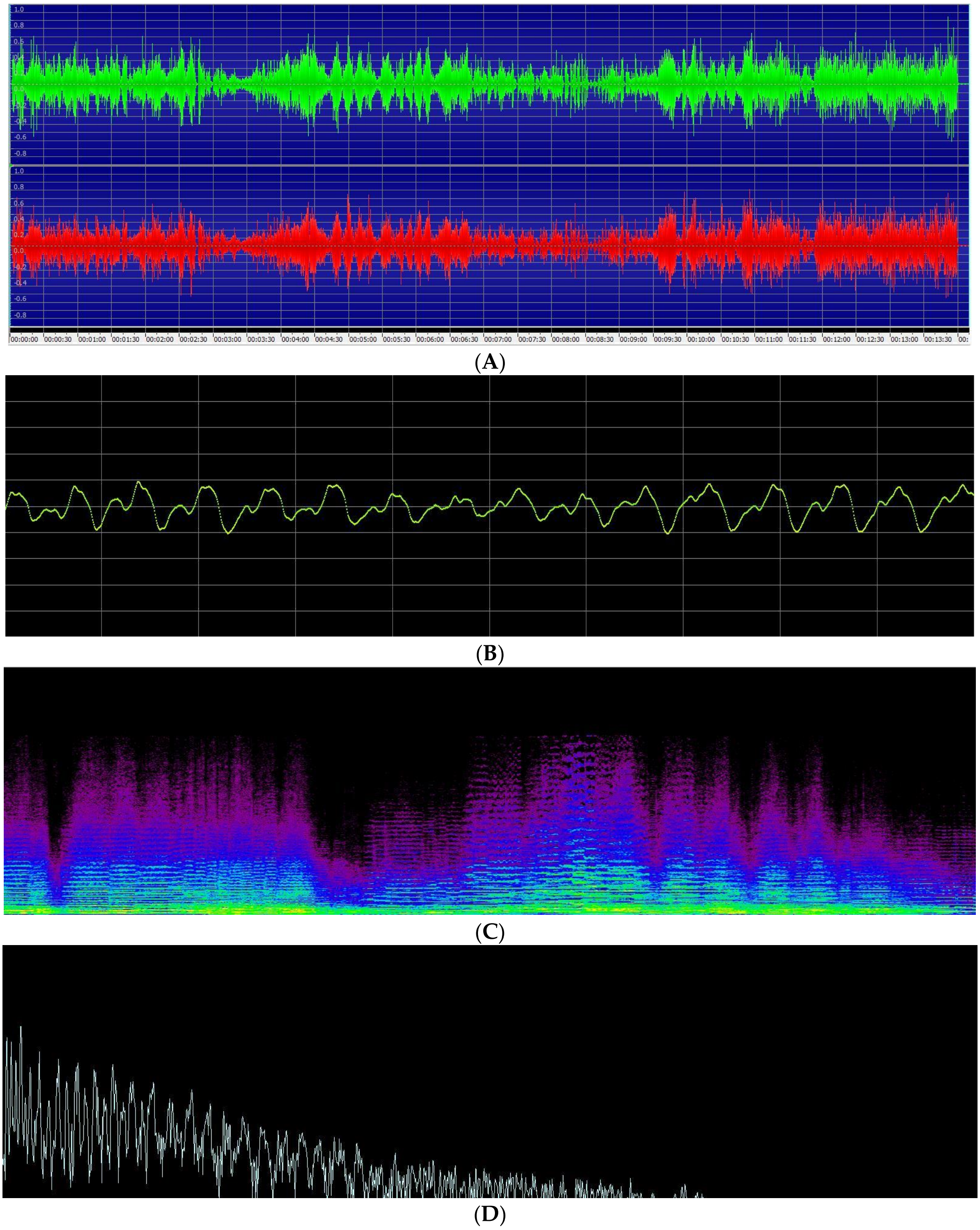


Figure 4. Acoustic characteristic diagram (CM, "Concerto pour Saxophone op.109") (**A**: Sound sampling; **B**: Waveform; **C**: Spectrogram; **D**: Spectrum).

2.2. The Effect of the Plant Acoustic Frequency Technology Generator on Lettuce Growth (Experiment 1)

The test was conducted in the experimental shed of Hefei University in March 2021. The soil used was 0~20 cm of topsoil from the pollution-free experimental soil on the campus of Hefei University. The background value of the soil was as follows: soil pH of 7.2, organic matter 3.2%, total nitrogen 1.7 g/kg, total phosphorus 1.2 g/kg, and total potassium 4.0 g/kg. The soil was air dried and ground, and then sieved through a 5 mm sieve. The variety of lettuce tested was Feicui lettuce (purchased from Chongqing Keguang Seedling Co., Ltd., Chongqing, China). The lettuce was harvested after 35 days of culture, and the growth indexes (plant height, root length, fresh weight of stem, leaf, and root) were determined by straight edge and electronic balance.

The test was conducted in two experimental sheds with two treatments in the silent frequency processing area (as the control area, CK1) and the acoustic frequency treatment area; the experimental shed is sound-proof to avoid interference from other sounds. Each treatment was repeated four times. The two experimental sheds were separated by 100 m (Figure 5), which can effectively avoid mutual interference. The distribution of the experimental sheds and the placement of the plant acoustic frequency technology generator are shown in Figure 5. The audio equipment adopted the fully automatic first-generation plant acoustic frequency technology generator (model: BL01-2011), produced by Beijing Lehe Tongfeng Agricultural Science and Technology Co., Ltd. (Beijing, China) (Figure 6). The audio content was a specific frequency sound wave, the dominant frequency was about 60 Hz, the audio loudness was 80 dB, and the maximum effective range of the audio frequency was about 100 m from the audio speaker. In this experiment, the playback time was set by a programmed timer. The above audio frequency was played for 3 h (08:30–11:30) every day from the lettuce transplanting period until 5 days before harvest.

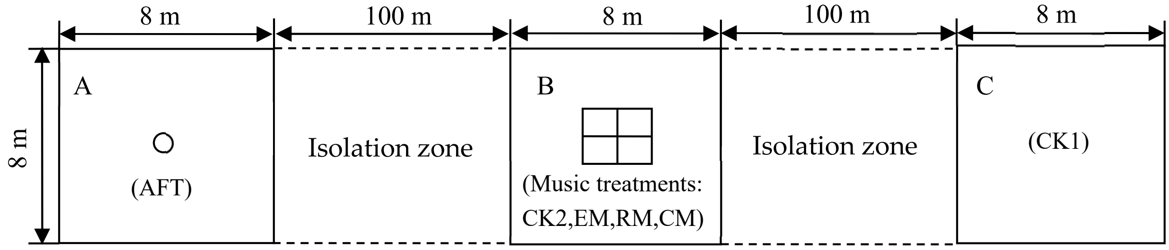


Figure 5. Schematic Diagram of Distribution Location of Experimental Shed.

Figure 6. The fully automatic first-generation Plant acoustic frequency technology generator (AFT model: BL01-2011).

2.3. *The Effects of Different Types of Music on Lettuce Growth (Experiment 2)*

The test was started in the experimental shed of Hefei University in April 2021. The lettuce seeds were soaked in 2% hydrogen peroxide for 10 min, and then washed with distilled water. The seedlings were raised with pre-washed sand that was placed in the turnover box. After the seedlings grew three cotyledons (12 days), the seedlings with the same growth momentum were selected and transferred to the 1/2 Hoagland nutrient solution for culturing, and were put in four artificial incubators to avoid interference from other sounds for different music treatments at the same time (Table 1). This experiment adopted four different treatments, including control (silent environment, CK2) and different styles of music: electronic music (EM), rock music (RM), classical music (CM). Each treatment was conducted in an artificial climate box and each treatment was repeated three times (Figure 5). The EM was selected from Bandari's "Annie's Wonderland", which was elegant and quiet; "Hey Jude" by The Beatles was selected as the RM treatment, which was high-pitched and excited; and Glazunov's "Concerto pour Saxophone op.109" was selected as the CM, which was solemn and thick. During music treatments, the music volumes were set to the extent that the human ear could not feel mutual interference. The volume of the three kinds of music was 80 dB, measured by the sound level meter (Figures 2–4). Music playback time was from 9:00 (a.m.) to 17:00 (p.m.). The nutrient solution was replaced every 4 days. Each incubator had 20 seedlings, and the treatment time was 30 days. Each treatment has 3 repetitions. After harvesting, the hollow was cleaned with distilled water 2–3 times, and its growth morphology indexes were measured.

Table 1. Different types of music used in this test.

Treatments	Kinds of Music	Song Name	Features	Play Time
1	Electronic music(EM)	Bandari "Annie's Wonderland"	Elegant and quiet	9:00–17:00
2	Rock music(RM)	The Beatles "Hey Jude"	High pitched and excited	
3	Classical Music(CM)	Glazunov "Concerto pour Saxophone op.109"	Solemn and thick	
CK2	No music	——	——	——

When harvesting, the lettuce was cleaned, the roots and stems were separated, and the fresh weight, plant height, root length, and other growth indicators of plant stems, leaves, and roots were determined by straight edge and electronic balance. The content of chlorophyll in the lettuce leaves was determined by spectrophotometry after the extraction with 95% ethanol. The data were analyzed by ANOVA using SPSS 26.0 software. The data were presented as mean or mean ± standard error.

3. Results

3.1. The Results and Analysis of Experiment 1 (The Effect of the Plant Acoustic Frequency Technology Generator on the Growth Morphology of Lettuce)

The audio frequency treatment improved the morphological indexes of the lettuce and significantly increased the plant height compared with the control. The fresh weight of the stem and leaf under audio frequency treatment was significantly higher than that of the control. However, there was not a significant difference in the longest root length and in the fresh weight of the root between the audio frequency treatment and the control. The chlorophyll content in leaves was significantly higher in the audio frequency treatment than that in the control (Table 2).

Table 2. Growth Physiological Indexes of Lettuce under Audio Treatment and Control Treatment.

Plant Height (cm)		Shoot FW (g)		Root Length (cm)		Root FW (g)		Chlorophyll (mg/g)	
CK1	AFT	CK1	AFT	CK1	AFT	CK1	AFT	CK1	AFT
26.39 ± 0.61	33.55 ± 1.13 **	31.21 ± 0.62	38.76 ± 0.66 **	23.25 ± 0.65	27.15 ± 0.87	11.95 ± 0.53	13.52 ± 0.43	1.47 ± 0.12	1.98 ± 0.15 **

Note: ** indicate that the differences between CK1 and AFT treatments were significant at the $p < 0.01$ level.

3.2. The Results and Analysis of Experiment 2 (The Effects of Different Kinds of Music on the Growth Morphology of Lettuce)

After the music treatment, the overall performance of the morphological indicators of lettuce was better in the music treatment than that in the control. A significant difference was not found in the growth of the lettuce plant height between electronic music and rock music, between classical music and the control, but the electronic music and rock music treatment significantly increased the growth compared with the classical music and the control treatment. The longest root length was under the electronic music treatment, the medium was under the rock music treatment, and the shortest was under the classical music and non-music treatments. The fresh weight of stems and leaves were the highest in the electronic music and classical music treatment, the medium in the rock music treatment, and the lightest in the control. There was no significant difference in the root fresh weight between the treatments of electronic music and classical music, and between the rock music treatment and the control. The results of root/shoot ratio (R/S) showed no significant difference among the four treatments. The chlorophyll content of the leaves was the highest under the electronic music and classical music treatments, the medium was under the rock music treatment, and the lowest was under the control (Table 3). The lettuce shoots (stems and leaves) were the edible parts. Compared with the control, the treatments of electronic music, rock music, and classical music increased the fresh weight of edible parts by 78.17%, 28.75%, and 63.35%, respectively (Table 3).

Table 3. Growth Physiological Indexes of Lettuce under Different Types of Music and Control Treatment.

Treatments	Plant Height (cm)	Root Length (cm)	Shoot FW (cm)	Root FW (g)	Root-Shoot Ratio R/S	Chlorophyll (mg/g)
EM	22.30 ± 0.62A	14.37 ± 0.61A	18.28 ± 0.53A	9.23 ± 0.56A	0.56 ± 0.02A	1.48 ± 0.07A
RM	20.27 ± 0.65A	11.71 ± 0.31B	13.21 ± 0.92B	6.35 ± 0.73B	0.49 ± 0.03A	1.12 ± 0.11B
CM	17.28 ± 0.61B	9.89 ± 0.23C	16.76 ± 0.91A	8.21 ± 0.58A	0.47 ± 0.02A	1.37 ± 0.03A
CK2	15.65 ± 0.82B	9.67 ± 0.25C	10.26 ± 0.52C	4.81 ± 0.15B	0.46 ± 0.03A	0.82 ± 0.02C

Note: Different capitalized English letters after the same column of data in the table indicate that there is significant difference in data statistics, and the difference level is $p < 0.05$.

In the experiment, the shape of the lettuce roots after the acoustic wave correction was different (Figure 7). As shown in Table 3, we measured the total root length, the root surface area per unit area of root tips and the average root diameter. Compared with the control, the AFT treatment significantly improved the total root length, root surface area, and average root diameter, but decreased the number of root tips per unit area (Table 3). After the music treatment, the EM and CM treatments significantly increased the total length and surface area of roots, and reduced the number of root tips per unit area ($p < 0.05$). The effects of the EM treatment on root length, root surface area, and root mean diameter were greater than those of the CM and RM treatments (Table 3).

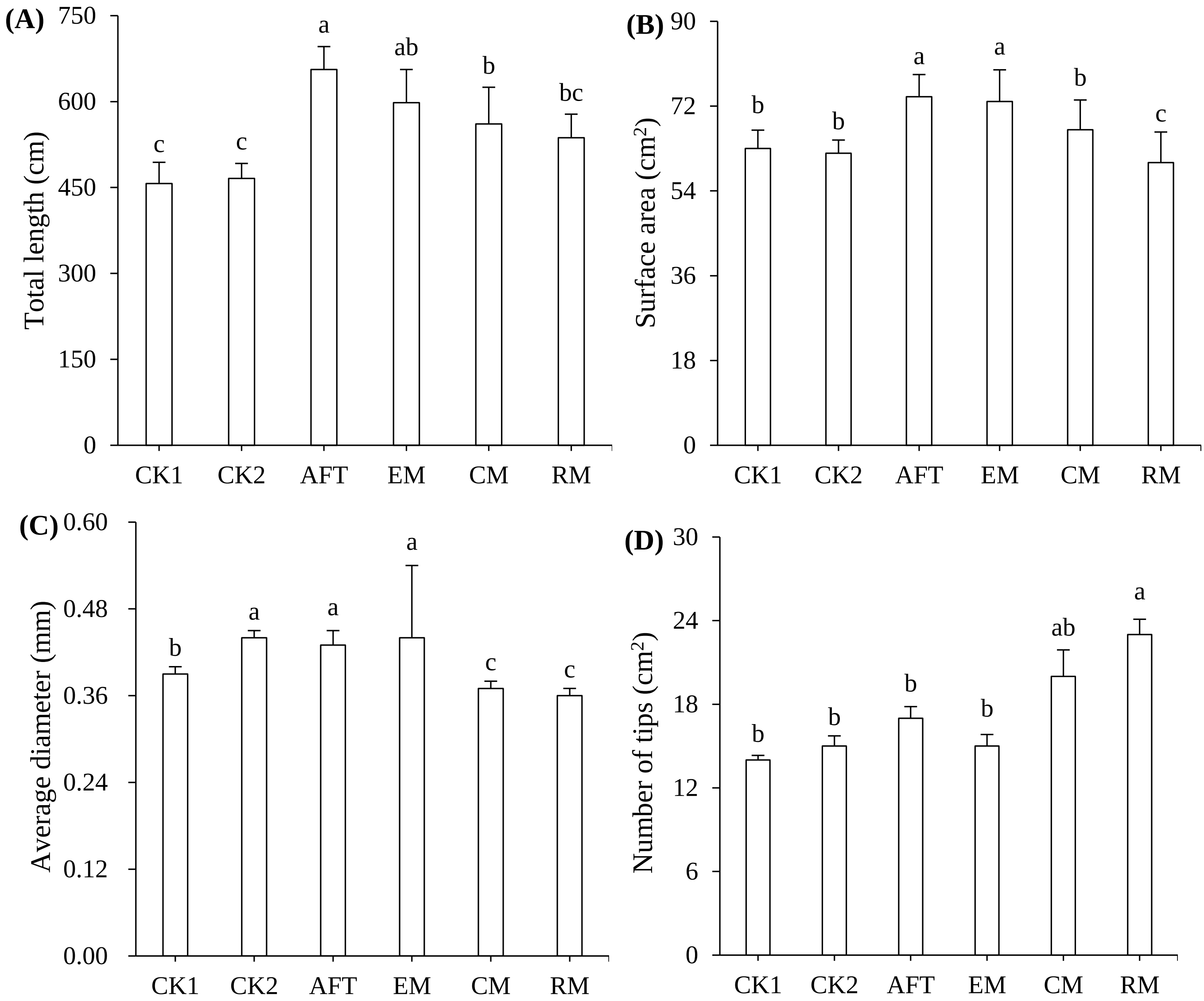


Figure 7. Comparison of morphological indexes of lettuce root system under sound wave and different types of music treatments. Indicators of (**A**–**D**) were measured by root scanner, std4800, WinRhizo. Different lowercase letters above the column indicate significant differences between different treatments, and the difference level is $p < 0.05$.

4. Discussion

4.1. Effect of the Plant Acoustic Frequency technology Generator on Plant Growth

As an application in physical agricultural production, plant audio control technology is a new technology that has developed in recent years. Its basic principle is to apply the processing of sound waves with specific frequencies to plants, to match their own sound wave frequency; this is in order to generate resonance, improve the efficiency of plant photosynthesis, accelerate its cell division, enhance the absorption, transmission and transformation of nutrients by plants, promote plant growth and development, and ultimately achieve the purpose of increasing production, quality and disease resistance [7,10,15,18]. In this process, the use of fertilizers and pesticides should be reduced as much as possible. On the other hand, music has certain influence on plant growth. If the sound is sharp and the vibration frequency is fast, the stimulation effect on plants may be better. For example, some researchers used the high-frequency ultrasound (about 20,000 vibrations per second) to stimulate potatoes, cabbage, wheat, vegetables, fruits, and trees, all of which had achieved significant increases in yield [21–25]. However, the more times plants receive ultrasound, the better [26,27]. It has been proved that a small amount of ultra-generated waves can promote cell division, that moderate ultrasound waves can inhibit cell division, and many ultrasound waves can cause cell death [23,28–31]. With regard to the influence of audio control technology on plant growth, the French first used audio processing technology to improve the germination rate of barley. Subsequently, the Sonic Bloom technology of Dan Carlson Company in the United States, with high-frequency (4~6 kHz) sound waves, was used to process crops [32–35].

In China, in Beijing, Shandong, Xinjiang, Shanxi, Tianjin, Jiangsu, Liaoning, and other areas, more than 30 kinds of field crops (such as strawberries, fruit trees, sweet pepper, tomato, cucumber, celery, kidney beans, edible fungi and other vegetables, as well as cotton, wheat, corn, and sunflower) have been tested with the plant acoustic frequency technology generators and have demonstrated the effect of yield increase. The plant acoustic frequency technology generator, creating sound waves and insect chirping, has played a good role in increasing the yield of a variety of vegetables (radish, water Spinach, cabbage, green vegetables, mustard, amaranth, soybean, eggplant, tomato, and cucumber) [7,15,26]. Plant audio control technology is a relatively new technology with a short history of development.

The above examples are consistent with the results in this study. Under the influence of the specific frequency sound wave produced by the plant acoustic frequency technology generator, the lettuce of the selected crops grew more vigorously than that without music treatment, especially in the yield of the edible parts of our plant. This is consistent with some of the research on cotton, sweet pepper, cucumber, and tomato [7,36–43].

4.2. Effect of Music on Plant Growth

Relevant reports and studies have shown that different types of music have different effects on plant growth. For example, Xiantuo Company in Osaka, Japan, used Yale to treat vegetables [14,19,20], and some researchers in France and Russia used classical music (Beethoven and Mozart's music) to treat tomatoes and beets to increase production [9,44]. Some concerts hinder the growth of plants, while some music will promote the growth of plants. The same kind of music that can promote the growth of plants has different effects due to different environments and playing methods. The plant audio frequency control technology developed based on this principle has attracted people's attention. Relevant research has shown that the use of this audio frequency control technology playing different types of music could significantly increase crop yield, improve nutritional quality, enhance disease resistance, improve early flowering and fruiting, extend storage time, speed up the degree of ripening, improve the seed germination rate and other functions. Scientists believe that music is a sound wave vibration of a certain frequency that can resonate with cells. The molecules that are originally in a static and dormant state will move harmoniously, promoting the activation of plant cells. Experiments have proved that music treatment could promote plant growth, and increase their chlorophyll and root system. However, there are exceptions. For example, if you play heavy metal music to a petunia, its leaves will droop and die after 4 weeks. Some plants, such as red beets, have no response to music. Different styles of music can have different effects on plants, among which beautiful and gentle melodies can affect the metabolism of crops, thus promoting the growth of crops. By playing music to affect the growth of plants, scientists cultivated 2.5 kg radishes, football-sized sweet potatoes, mushrooms like washbasins; scientists placed earphones on tomatoes and let them listen to music for 3 h every day. The tomatoes grew to more than 2 kg [9].

Music can promote the growth of plants, mainly because of the stimulation of sound waves. Many stomata are distributed on the surface of plant leaves, and stomata are important channels for gas exchange and water evaporation between plants and the external environment. In the environment of playing music, the music sound will generate rhythmic sound waves when it travels through the air. This vibration can stimulate the stomata on the surface of plant leaves and increase the openness of stomata. When the stomata are enlarged, the amount of photosynthetic materials (carbon dioxide) absorbed by plants is relatively increased, which makes photosynthesis becomes more active, thus increasing the amount of synthetic organic materials. At the same time, the respiration of plants is also enhanced, which provides more energy for the growth of plants and makes them more vigorous.

The above examples are consistent with the results of this study. Different audio control technologies (electronic music, rock music, and classical music) have promoted the growth of lettuce, especially under the influence of electronic music, and the production of edible parts has increased significantly. This is similar to the results of some studies on rosemary plants [45–48].

4.3. Difference in Effect of the Plant Acoustic Frequency Technology Generator and Music on Lettuce

Some studies have shown that sound wave stimulation could increase the content of polyamine compounds (PAS) and indoleacetic acid (IAA) in plants, which can influence plant cell division and plant morphological changes, and promote the formation of plant leaves, vascular bundles and buds [3–10]. In this study, AFT and EM treatments increased significantly. In addition, the main pigment for plants to absorb solar energy in photosynthesis is chlorophyll. The content of chlorophyll directly affects the light and intensity of leaves. In this experiment, the plant acoustic frequency technology generator (AFT) promoted the chlorophyll content in lettuce leaves (Table 2), thereby improving photosynthesis and increasing the biomass. Among the three types of music, the EM treatment had a good effect on plants. The effect on lettuce photosynthesis can be explained as the "stimulus" of music processing, which can affect the yield of lettuce. It may cause its own physiological changes in the process of "feeling" music, resulting in changes in growth ability. The author also investigated the content of chlorophyll in lettuce leaves in two experiments. The results showed that the music emitted by the plant acoustic frequency technology generator promoted the increase in the chlorophyll content of lettuce leaves, thus promoting photosynthesis. Different types of music had different effects on the chlorophyll content in the lettuce leaves. Among them, the electronic music treatment had the largest role in promoting photosynthesis.

It can be seen that, under the "stimulation" of audio control technology, the output of some crops can be effectively improved, which is an effective way to realize pollution-free ecological agriculture. At the same time, the crops themselves may have many physiological changes in the process of "enjoying" audio control technology, which will lead to changes in growth capacity [49–52]. The present results showed that different plants had different responses to acoustic stimulation at different growth stages, but the mechanism is still unclear. Therefore, further research and confirmation of these results are needed. The audio control technology can stimulate the growth of some plants, while unwanted plants (such as weeds) can be suppressed, which is caused by the electromagnetic wave of plants [53–55]. In this case, the impact of the setting of the acoustic pulse frequency on the plant vitality enters the molecular level. In addition, the mechanism of how sound affects cell cycle and thus plant growth needs further research, comparison, and scientific understanding. However, the research needs further exploration in this area, musicology, environmental science, agronomy, and other disciplines. At present, there are still many unstable factors (temperature, light, and humidity) affecting the technology. Its technology development and equipment optimization are still of value to further research and can be improved.

5. Conclusions

The specific frequency sound wave treatment produced by the plant acoustic frequency technology generator significantly increased the growth of lettuce compared with the condition of silent environment processing. Treatments of different audio control technologies (electronic music, rock music, and classical music) promoted lettuce growth; there was a particular increase in the output of edible parts under the influence of electronic music. The final results indicated that the specific frequency sound wave treatment produced by the plant acoustic frequency technology generator enhanced the chlorophyll content of lettuce leaves, thus promoting photosynthesis. Different types of music had different effects on the chlorophyll content of lettuce leaves, and electronic music treatment had the largest effect on the photosynthesis of lettuce. From the effect of the plant acoustic frequency technology generator and music on lettuce growth, we can see the functionality of audio control technology and its application potential in ecological agricultural production. Of course, as the development of ecological agriculture is still in the development stage, the verification or optimization of new technologies is more important.

Applying audio control technology to ecological agricultural production is a potential project. Constantly exploring the law of audio control technology and agricultural coupling can reduce the environmental pollution caused by pesticides and fertilizers, protect the ecological environment, make ecological agriculture the driving force for the sustainable development of modern agriculture, and thus promote the development of agricultural science and technology. On the whole, research on the impact of audio control technology on plant growth is still in the stage of experience exploration and data accumulation. In the future, the author will continue to study this aspect, and hopes that more experts and scholars in musicology and agricultural science can participate in the research on this emerging technology to benefit mankind.

Author Contributions: S.W. preformed investigation. S.W. and Q.X. performed conceptualization. S.W performed writing. Q.X. performed formal analysis and project administration. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Provincial "double base" course of Anhui Province "Basic music theory "and "saxophone", Provincial Quality Project of Anhui Province(2018kfk039), National Natural Science Foundation of China (41501355), the Talent Research Fund Project of Hefei University (18-19RC11), the Borrowing Transfer to Supplement Foundation of Hefei (J2019D04), the double base demonstration teaching organization "Department of Food Engineering" of Anhui Provincial Department of Education, the Anhui Quality Engineering Project Practice Education Base (2021xqhzsjjd069), Hefei University Quality Engineering Project Course Ideological and Political Demonstration (2021hfukcsz09), and Anhui Province Philosophy and Social Science Planning project:" Study on the evaluation and Optimization Strategy of Music Sound Environment in Anhui Urban Public Space" (AHSKQ2019D081).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This paper is the result of Anhui Province Philosophy and Social Science Planning project: "Study on the evaluation and Optimization Strategy of Music Sound Environment in Anhui Urban Public Space" (AHSKQ2019D081).

Conflicts of Interest: The authors declare no conflict of interest.

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