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Soundscapes in Plant Cultivation: A Literature Review on Music's Influence in Plant Growth

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Abstract

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Preface

Music has long been associated with human emotions, creativity, and cultural expression. There are also indications that music of different wavelength can promote plant growth. Lidl Sweden wanted RISE to immerse into the subject by making a review of existing scientific publications as a first step to see if there are ways to promote wellbeing for both humans and crop development by the means of music.

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Summary

Music has long been associated with human emotions, creativity, and cultural expression. There are also indications that music of different wavelength can promote plant growth. Sound is a mechanical wave of pressure that requires a transmission medium to propagate. The wave of pressure that a crop is exposed to might not always be audible to the human ear but can be perceived by sensors and affect the plants. Acoustic and vibrational energy has distinct dynamic advantages; it enables rapid and temporally well-defined, signals. Ultrasounds has been shown to affect the biosynthesis of plants, resulting in production of a wide range of secondary metabolites. An example is flavonoids, that enhance seed germination, flowering, growth or defence mechanisms.

There have been several experiments with various types of music where different crops have been exposed to the music for different length of time and in different growth stages. For example, rock music was found to significantly inhibit the germination of alfalfa seeds. Results also showed that Gregorian chant, new age, and waltz music were able to induce lettuce seedlings to produced significantly longer roots and stem. Another experiment showed that treatments of with electronic music, rock music and classical music promoted lettuce growth compared to no music, especially significant was the increase in growth of the edible parts under the influence of electronic music.

It has been found that audible sound at 125 Hz and 250 Hz frequencies, plant genes are more active in DNA code translation, and as a result, growth and development are increased. It would be interesting to test the effect on plant development on even more species grown close to a transmitter of different music styles to try to identify why they respond differently to a range of decibel and hertz.

From an applicative point of view, in-depth knowledge of plant species sensitivity towards sound and music can be used to stimulate the biosynthesis of targeted secondary metabolites, and thereby obtaining bioactive enriched products with less hazardous chemical inputs, which can enhance sustainable natural environment.

Sammanfattning

Musik har länge förknippats med mänskliga känslor, kreativitet och kulturella uttryck. Det finns också indikationer på att musik med olika våglängder kan främja växters tillväxt. Ljud är en mekanisk tryckvåg som kräver ett medium för att fortplanta sig. Den våg av tryck som en gröda utsätts för är inte alltid hörbar för det mänskliga örat men kan uppfattas av sensorer och påverka växter. Akustisk och vibrationsenergi har tydliga dynamiska fördelar; den möjliggör snabba och tidsmässigt väldefinierade signaler. Ultraljud har till exempel visat sig påverka biosyntesen av växter, vilket resulterar i produktion av ett brett spektrum av sekundära metaboliter. Ett exempel är flavonoider, som förbättrar grobarhet hos frön, blomning, tillväxt eller försvarsmekanismer.

Det har gjorts flera experiment med olika typer av musik där olika grödor har exponerats för musik under olika lång tid och i olika växtstadier. Till exempel visade sig rockmusik avsevärt hämma groning av alfalfafrön. Resultaten visade också att gregoriansk sång, new age-musik och vals kunde få salladsplantor att producera betydligt längre rötter och stam. Ett annat experiment visade att behandlingar med elektronisk musik, rockmusik och klassisk musik främjade salladstillväxt jämfört med ingen musik, särskilt signifikant var ökningen av tillväxten av de ätbara delarna under påverkan av elektronisk musik.

Det har visat sig att växtgener är mer aktiva i DNA-kodöversättning efter att de exponerats för hörbart ljud vid frekvenser mellan 125 - 250 Hz och som ett resultat ökar tillväxten och utvecklingen. Det skulle vara intressant att testa effekten på växtutvecklingen på ännu fler arter som odlats i anslutning av högtalare med olika musikstilar för att försöka identifiera varför de svarar olika på olika decibel och hertz.

Ur en tillämpningssynpunkt kan fördjupad kunskap om växtarters känslighet för ljud och musik användas för att stimulera biosyntesen av riktade sekundära metaboliter som eventuellt kan minska behovet av kemiska insatser.

1 Background

RISE - Research Institutes of Sweden, has been requested by Lidl Sweden to make a review of the scientific studies published on the topic of how music influence has on plant development. Lidl has previously screened the field of popular science and found out that music is not only affect human emotions, but also affects plant growth in a positive way. This report will present the results from the scientific field and conclude the potential within the field.

2 Introduction

As plant do not have a nervous system humans tend to overlook other options of sensing the surroundings. However, recognizing and making the most optimal choices to undergo cellular, molecular and structural changes is essential for survival, adaptation and evolution of also for plants (Allievi, 2021; Bhandawat, Biological relevance of sound in plants, 2022). Plants grow and reproduce within a highly dynamic environment that can see abrupt changes in conditions, such as light intensity, temperature, humidity, or interactions with biotic agents (Kollist, 2019). Unlike animals that express their response to the external inputs rapidly, plants are sessile creatures reacting in a much more subtle manner that mostly goes unnoticed.

Light

The most obvious external stimuli is light, which is essential for the crop to produce energy for their growth process, but different wavelengths will produce diverse physiological responds such as for example taller or shorter plants, time for initiation of flowering or accumulation of antioxidants (Al Murad, 2021).

Herbivory

It is also well known that some common crops that has been exposed to saliva of herbivorous larvae will increase emissions of a specific compound of volatiles that attracts natural enemies of the larvae (Alborn, 1997). There is also evidence of direct systemic defence after an attack, which makes the crop more resistant to herbivory. Many compounds produced as a response by the crop, act directly on the herbivore as they are toxic, repellent, or antinutritive for herbivores of all types (Mithöfer, 2012).

Touch

Some plants, such as for example *Mimosa pudica* and *Dionaea muscipula* will rapidly change the position of their leaves, triggered by touch.

Sound

The use of sound and music to improve the health of living organisms is not a new idea. The beneficial and harmful effects of sound in terms of music were recognized even by by preliterate cultures; early civilizations in Mesopotamia, Egypt, Israel; Greek Antiquity; Middle Ages, Renaissance, and Baroque (Thaut, 2015). To gain knowledge of how the crop performance of various plant species is affected by sound waves, there is a need for this short review of the front line of science within the field.

3 Method description

The review has been made by gathering the existing knowledge in the field of soundwaves and music related to crop performance in databases for scientific publications. Older research is combined with new experimental data to build the knowledge base. In many earlier studies the results have been inconsistent and variable depending on different locations. Statistical evidence has not been presented in some of the studies and this will be commented in this report in relation to the specific publication. Some of those studies are presented in the review, as they can be viewed as pilot-studies that would be interesting to follow up with a scientific setup to re-evaluate the results. In addition, the sound used in some experiments was not standardized, and was not performed on the uniform and consistent hertz (vibration) and decibel (strength) levels of the signals.

4 The perception of and respond to sound in plants

Sound is a mechanical wave of pressure that requires a transmission medium to propagate. The definition of sound is oscillation of audible waves of pressure transmitted through a medium such as a gas, liquid or solid, and each sound is characterized by its wavelength hertz (Hz), intensity (decibel), speed, and direction. The audible sound that human can hear falls into frequencies ranging from 20 hz- 20,000 hz (hertz) (Chandrakala, 2019). Frequencies above this range is known as ultrasound and frequencies below is known as infrasound.

The wave of pressure that a crop is exposed to might not always be audible to the human ear but can be perceived by sensors and affect the plants. Acoustic and vibrational energy has distinct dynamic advantages; it enables rapid and temporally well-defined, signals. Mechanical energy imparted to a plant stem can induce it to sway to its resonant frequencies, usually in the infrasound range, which will be a function of the height and mechanical properties of its tissues. As described in a review by Wu et al (2023), ultrasounds can also affect the biosynthesis of plants, resulting in production of a wide range of secondary metabolites. An example is flavonoids, that enhance seed germination, flowering, growth or defence mechanisms (Wu, 2023). Plants need to perceive and respond to wind or wave induced movement to acclimate to a given environment. They will even sway in a harmonic motion at low resonant frequencies (Telewski, 2006). Although plants can effectively absorb sound and even generate sound via wind-induced resonance of various structures such as needles and spines (for example, the whispering winds in a pine forest), the question is if they perceive sound. And the following question is if perceived, how do they respond to sound? Figure 1 shows a brief overview of the wide implications of sound responses in plants.

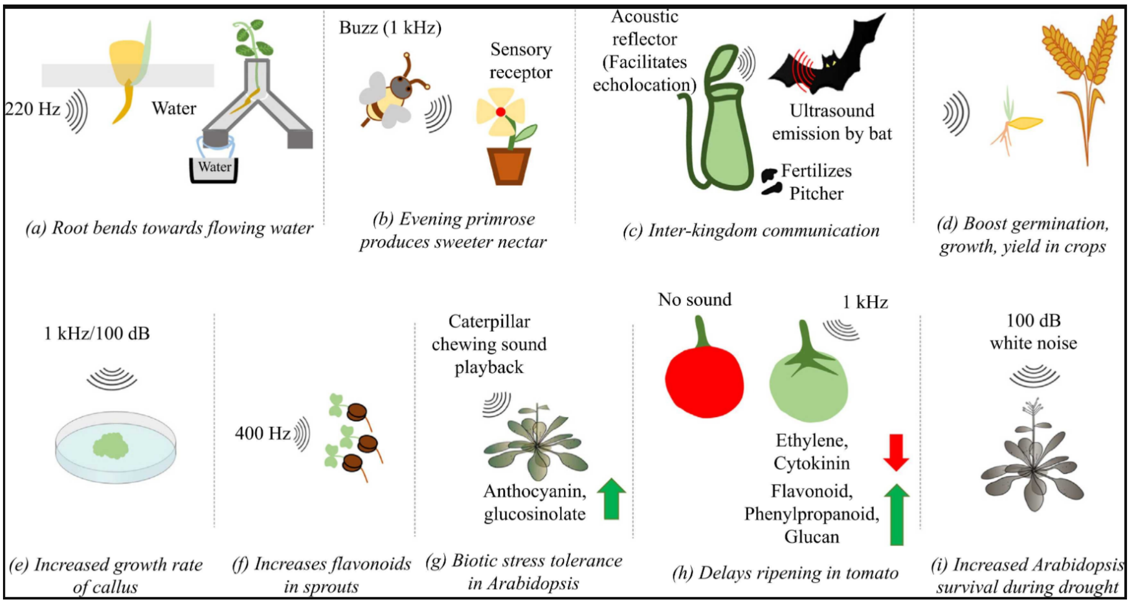

Figure 1. Evidence showing biological significance of sound in plants. (a) Root detects and bends towards flowing water sound. (b) Flower produces sweeter nectar perceiving bee buzz to increase the chances of pollination. (c) Facilitates echolocation of bat in return for getting fertilizer. (d) Enhances growth indices in various crops. (e) Promotes callus growth and regeneration. (f) Enhances production of functional metabolites. (g) Elicits biotic stress response. (h) Delays ripening and keeps tomatoes firm for extended period. (i) Increases drought tolerance. (Bhandawat, 2022)

4.1 The sound of herbivory

It has been shown in several studies that sound waves can impact plant fitness and may provide a trigger for adaptation to adverse environmental conditions (Demey, 2023). One study that played recorded chewing vibrations from a larvae gave a respond of chemical defence in exposed plants (Appel, 2014).

Vibrational signals are likely to complement other signals that plants receive from herbivory as none of these mechanisms has been shown to transmit signals to all plant parts as fast as mechanical vibrations. Plants can take advantage of this rapid source of information about herbivory to produce a systemic response, via perception of the mechanical vibrations produced by feeding (Appel, 2014).

In the study by Kolasch *et* al (2020), scientists tested the crop response to different sounds of herbivory from ten species of butterfly larvae from the *Hymenoptera* family *Arabidopsis thaliana* plants. The study revealed that the plants exposed to chewing vibrations produced greater amounts of chemical defences (such as the compounds glucosinolate and anthocyanins) and that the plants distinguished chewing vibrations from other environmental vibrations such as wind and insect (leafhopper) song. The response was very similar also when they tested the different sounds of the ten species of larvae. These results suggest that feeding vibrations provide a consistent set of cues for plant recognition of herbivores (Kollasch, 2020).

4.2 Tuning in to enhanced germination

Ultrasound treatment of seeds is a green technology that show promises to have an impact on the food industry, enhancing germination and seedling development in different species through the stimulation of water and oxygen uptake and seed metabolism (Nogueira, 2024). Low-frequency and high-intensity ultrasound (20–100 kHz; 10–1000 W $(cm^2)^{-1}$ may penetrate and modify the properties of a material such as a seed coat or increase the speed of a process, such as germination (Rezaei, 2015). The effect is explained visually in figure 2. The pulses of sound waves can either cause water bubbles to oscillate or burst. This treatment has been shown to increase inertial flow during germination (Patero, 2015), improving nutrient transportation and absorption from the soil and, above all, water and oxygen uptake by the seeds, which triggers seed hydration (Yaldagard, 2008; Miano, 2018; Silva, 2014). Different electron microscopy studies have reported the formation of fissures and cracks in the seed surface, validating the assumption that ultrasound increases the porosity (López-Ribera, 2017; Bonto, 2021; Ding, 2018).

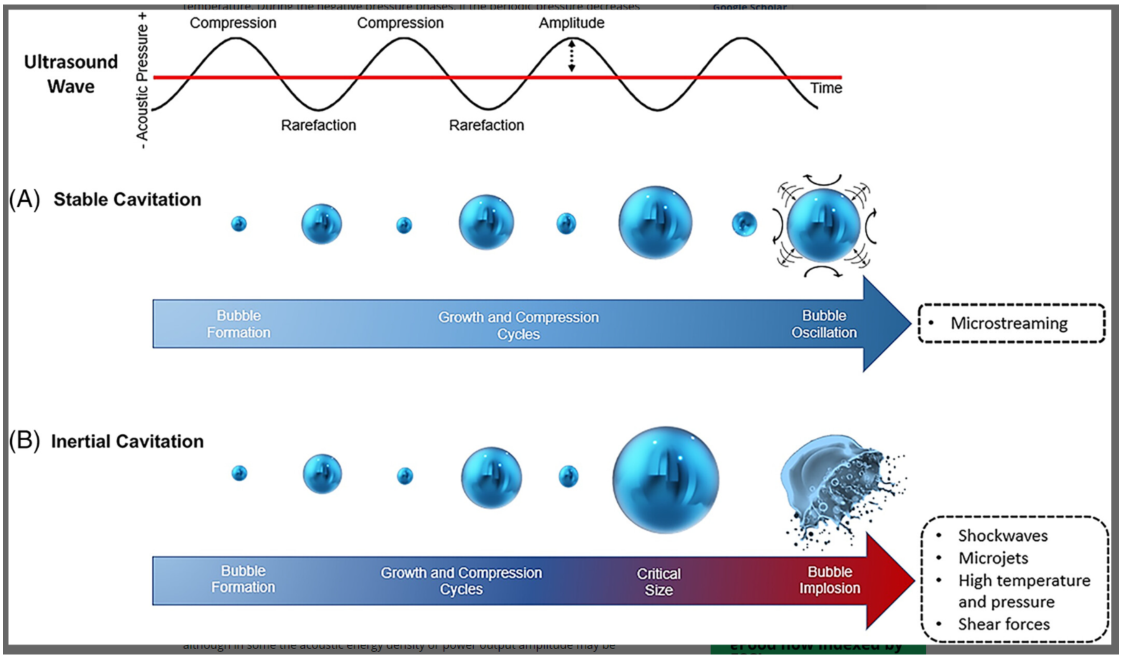

Figure 2. The development and effects of acoustic stable (A) and inertial (B) cavitation processes. (A) illustrates stable or non-inertial cavitation, which occurs at low intensities of sonication (1–3 W$(cm^2)^{-1}$). In this type, the bubbles oscillate at the same frequency as the applied ultrasonic waves, exhibiting equilibrated size changes. The oscillation of the bubble generates microstreaming, causing flow around the bubble. These oscillations persist for numerous acoustic pressure cycles before the bubbles eventually fragment. (B) Non-stable or inertial cavitation, induced by high-intensities of sonication (>10 W$(cm^2)^{-1}$). In this case, the bubbles grow in size due to the accumulation of dissolved gas from the liquid medium. As their size reaches the resonance frequency, these bubbles collapse, resulting in inertial, transient, or collapse cavitation. The collapse leads to fragmentation into smaller bubbles, which can penetrate tight areas and act as new cavitation nuclei. The smaller bubbles can undergo expansion and collapse, generating large shock waves accompanied by thermal, mechanical, and chemical effects (Rezaei, 2015).

4.3 A strech to hertz after germination

Studies have shown that certain vibrations frequencies has resulted in a trigger of plant hormones that regulate elongation. Takahasi et al. (1992) reported that treatment of germinating rice or cucumber seeds exposed to 50 Hz vibration for 72 h resulted in stimulation of the hypocotyl elongation rate (Takakashi H, 1992). Similar results have been reported in Arabidopsis (Johnson KA, 1998).

4.4 Roots and frequency

Systematic studies have found that some frequencies have a greater influence than others in root growth (Telewski, 2006). For example, young roots of corn (*Zea mays*) grow towards the source of continuous tones, transmitted as airborne or waterborne sound, and respond optimally to frequencies of 200–300 Hz (Gagliano M, 2012), figure 3.

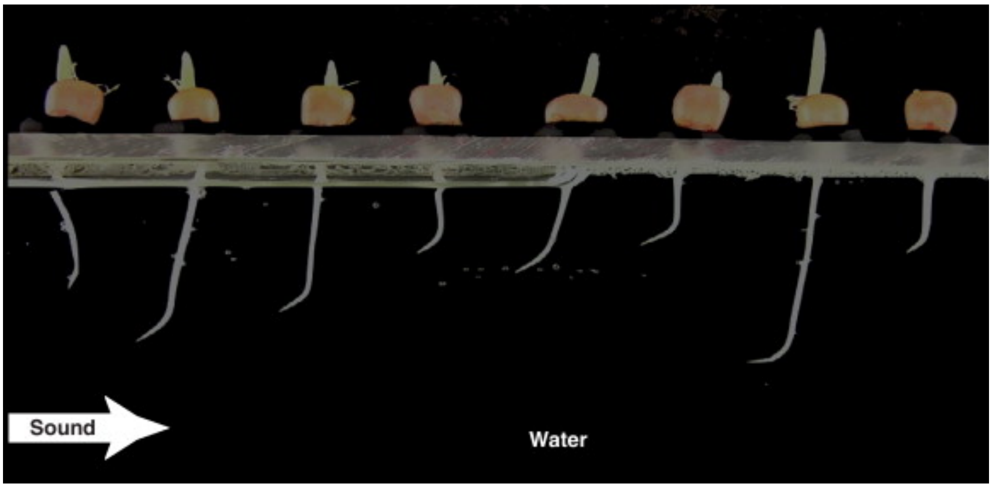

Figure 3. Behavioural response of young roots of Zea mays to a continuous 220 Hz sound coming from left field (white arrow). Root tip clearly bend towards sound source. Modified from (Gagliano M, 2012)

The kiwi (*Actinidia chinensis*) has also been used in experiments with sound waves and their effect of root development has been analysed. A statistically significant effect was measured as the sound waves stimulated increase root activity, total length and number of roots whereas, the permeability of cell membranes decreased. The optimum growth was obtained at 100 decibel and as the intensity of the sound exceeded 110 decibel cell membranes were damaged (Yang, 2004). Furthermore, it was found that ATP (adenosine tri-phosphate) significantly increased at 100 dB and sound frequency of 1 kHz. ATP is a high-energy molecule used for energy storage by organisms. The increase of ATP content indicates that the anabolism was strengthened in cells (Xiaocheng, 2003).

Seedlings of 89 garden peas (*Pisum sativum*) was used as model plants to investigate the mechanism by which roots sense and locate water. The researchers found that roots were able to locate a water source by sensing the vibrations generated by water moving inside pipes, even in the absence of substrate moisture. When both moisture and acoustic cues were available, roots preferentially used moisture in the soil over acoustic vibrations, suggesting that acoustic gradients enable roots to broadly detect a water source at a distance, while moisture gradients help them to reach their target more accurately (Gagliano, 2017).

4.5 Flowering and fruitification in tune

An experiment with strawberry plants was treated with a sound at the intensity of 100DB and the frequency of 40－2000Hz respectively 3 hours every day. The specific frequency was adapted to a meridian system used in Chinese medicine. The results showed that the number of flowers and fruits as well as the content of chlorophyll increased (Meng, 2012), figure 4. The researchers relate the results to factors related to improved photosynthesis by stimulating chemical responds within the plants (Meng, 2012).

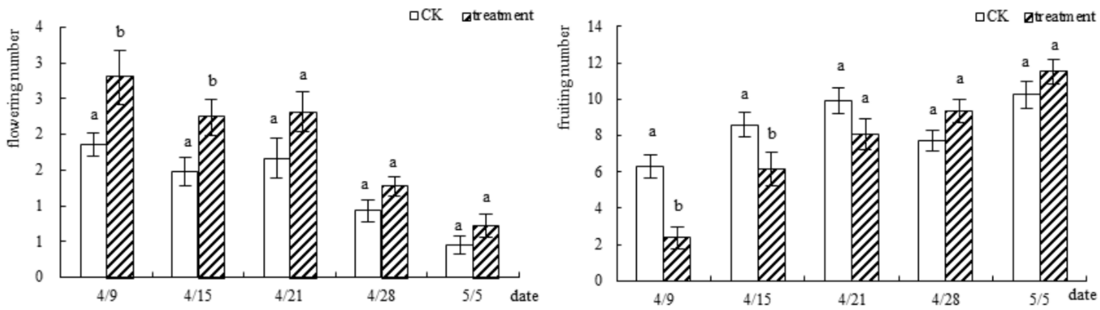

Figure 4. a) Increased number of flowers in sound treatment at all the dates of measuring; b) fruit development was higher in the later measurements of the crop (Meng, 2012).

The Chinese meridian system of specific frequency has also been tested outdoors on cotton, where the effect in increased bud yield (11-14%) was related to the distance of the source of the sound (Hou T. L., 2010). Several vegetable crops such as sweet pepper, cucumber and tomato has also been tested with the same type of schedule for frequencies during growth and are reported to giver higher yields and have increased tolerance to pests ((Hou T. L., 2009; Cai, 2012; Jiang, 2012). The publications are in Chinese except for the abstracts, which makes it hard to validate and verify the results for a non-native Chinese speaker.

4.6 Music and crop performance

Wikipedia contributors defines music as the arrangement of sound to create some combination of form, harmony, melody, rhythm, or otherwise expressive content. However, definitions of music vary depending on culture, though it is an aspect of all human societies and a cultural universal.

The perception and response of plants to music, has been the subject of debate to many practitioners of agriculture, students and researchers for many decades (Weinberger, 1973). There have been several experiments with various types of music where different crops have been exposed to contrasting types of music for different length of time and in different growth stages. It has been found that audible sound at 125 Hz and 250 Hz frequencies, plant genes are more active in DNA code translation, and as a result, growth and development are increased (Ekici, 2007).

4.6.1 Mustard and violins

Mustard (*Brassica juncea*) was used as an experimental crop as a research group tested the effect on morphologic traits affected by classical music genre violin Canon D major Johann Pachelbel with a frequency range of 550-1200 Hz. The sound level consists of three levels: 70-75 dB, 80-85 dB and 90-95 dB being played for three hours per day. There were 10 plants in each of the treatments, where one was without music. Both germination and plant growth were monitored. Sound exposure at 70-75 dB sound level generally produced highest values for all morphological characteristics. Statistical analysis showed that sound exposure at 70-75 dB sound level produced highest productivity average weight, 22,5 grams per plant, while control plants produced an average weight only 15 grams per plant. The conclusion of the study was that violin music stimulation resulted increased green mustard productivity, especially at low sound level (Prasetyo, 2021). The effect on different parameters is presented below. The variation of the measured parameters within the treatments and the statistical model being used was not presented in the publication, which lowers the scientific value of the results. It is still an interesting a study that presents the experimental setup thoroughly.

4.6.1.1 Germination

The exposure of violin music at various sound levels resulted in highest germination rate (100%) with the sound levels of 70-75 dB and 80-85 dB produce the highest germination rate after, while the lowest was found in mustard seeds without music (control) of 90% (Prasetyo, 2021).

4.6.1.2 Plant height

The sound level of 70-75 dB gave a higher plant height when compared to sound levels of 80-85 dB and 90-95 dB 28 days after seeding (DAS). The lowest plant height increase from 28 DAS to 46 DAS was found at sound levels of 90-95 dB and the highest increase in plant height was found at sound levels of 70-75 dB (Prasetyo, 2021).

4.6.1.3 Leaf area

Measurement started at 28 DAS when the 4th internode[1] leaf had fully opened. Sound exposure treatment with different levels affected the leaf area at the three levels of sound presented. The sound level of 80-85 dB gave a higher increase in leaf area compared to the other treatments (Prasetyo, 2021).

4.6.2 Natural sounds and flute

An experiment analysing the percentage of okra and zucchini seeds sprouting with or without music was made by Creath et al (2004). They used sounds of nature such as birds and echoes, are mostly improvised, contain short phrases with pauses for breath, and are predominantly performed on Native American flute. This music was chosen because it contained natural sounds, the music was gentle, and it was preferred by the experimenter who listened to it many hours a day during the course of the study. The treatment was also compared to a constant pink noise[2]. The research team could see a strong statistical increase in seed germination within 72 hours for the music treatment compared to seeds grown without music or with noise. The effect was greater with okra than with zucchini in this experiment (Creath, 2004). There was no reporting of decibel, hertz or wavelengths used in the experiment.

4.6.3 Indian music

A very small pilot trial Tagetes was set-up to investigate the effect of "soft Indian music", "Mediterranean music" and "noise" played for four weeks, compared to plants grown with no additional music or noise. Conditions such as water, light and fertilizer where comparable. It was observed that "Light Indian music" promoted elongation of the plant compared to the one growing with no music. The number of buds and flowers were higher on the treated plant. A particular leaf marked on each plant to monitor the growth also showed a higher gain in its length after exposure to music. Similarly, on exposure to meditation music, the different factors that were selected as attributes of growth, i.e. height, number of buds and flowers, including the leaf length were with music than without. There were only two pots in each musical treatment, which makes the trial results an anecdote, as no statistical evaluation is possible and the result can be based on coincidence. It is still a result that could be interesting to evaluate in a proper experiment with many more repetitions (Chowdhury, 2015).

Findings from another pilot-study showed that protein content in plants such as soya (*Glycine max*), spinach (*Spinacia oleracea)* and wheat (*Triticum asteivum*) was positively affected by Indian classical ragas (Reddy, 2013), but statistical analysis was not made even though nine repetitions of plant were used. The results should be viewed as an interesting anecdote and it could be interesting to make a scientific trail with similar methods but with a scientific approach.

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[1] Nodes are the points where leaves, branches, or flowers emerge from the stem. The internode is the slender section connecting these nodes.

[2] According to Wikipedia; In pink noise, each octave interval carries an equal amount of noise energy. Pink noise sounds like a waterfall. It is often used to tune loudspeaker systems in professional audio. Pink noise is one of the most commonly observed signals in biological systems.

4.6.4 Which musical style resonates with lettuce and alfalfa?

Eight different music genre was played for 12 hours in an experiment with lettuce (*Lactuca sativa*) and alfalfa (*Medicago sativa*), with 12 seeds of each species in each treatment with an additional treatment of no music. There were 60 replicates of each treatment. The measurements of germination, root length and hypocotyl[3] length was measured after 7 days. The treatments were:

1) Control (0 dB, 0Hz)
2) Gregorian Chant (79 +/-9 dB, 131~349 Hz)
3) Baroque (91 +/-9 dB, 123~1661 Hz)
4) Classical (84 +/-7 dB, 466~1397)
5) Jazz (93 +/-4 dB, 207~557)
6) Rock (87 +/-8 dB, 196~294)
7) Nature sound (90 +/-6 dB, pink noise)
8) New-age (87 +/-4 dB, 73~1760)
9) Waltz (85 +/-4 dB, 147~1319)

(Lai, 2020)

The results on different measured parameters are presented below.

4.6.4.1 Seed germination

It was observed that alfalfa seeds had a positive response in germination as the seeds were exposed to classical, nature sound, and waltz music which resulted in 100% germination, whereas rock music significantly reduced the germination (91.7%). However, the inhibitory effects of the rock music treatment on alfalfa seed germination were not as profound as one could expect, with over 90% germination. Results showed no significant differences between the different types of music on the germination of lettuce seeds (Lai, 2020).

4.6.4.2 Root development

In lettuce seedlings, results showed a significantly longer first root in the treatments with Gregorian chant, new-age and waltz treatments compared to the control. Of these three treatments, seedlings in the Gregorian chant and waltz treatments produced the longest root, which were significantly longer than those exposed to new-age music. No significant differences were found between the treatments in the root growth of alfalfa seedlings (Lai, 2020).

[3] The term “hypocotyl” refers to the part of a seedling that constitutes the stem and is located between the first leaves and the root.

4.6.4.3 Length of the hypocotyl[4]

The hypocotyls of the lettuce grown in the music treatments were significantly longer than the control treatment, except for those grown with baroque, classical, and rock music treatments, which had similar hypocotyl lengths to those in the control treatment. The longest hypocotyl was produced with jazz and waltz music treatments, whereas those germinated in the control treatment produced the shortest of all treatments (Lai, 2020).

In contrast to lettuce seedlings, the response of the growth of alfalfa hypocotyls to music was less pronounced. Except for jazz and nature sound, which had significantly shorter hypocotyls, the hypocotyl length of alfalfa seedlings grown without any music was comparable to the other music treatments (Lai, 2020).

4.6.5 Raving lettuce

Another experiment that also used lettuce (*Lactuca sativa*) as a test plant measured the effects on plant performance with three types of music: electronic music, rock music, and classical music. The music played for three hours per day during at 80 db, with the dominant frequency around 60 Hz for 30 days. There were 20 seedlings for each treatment and three repetitions. The measurements were analysed for statistical significance levels (Wang, 2023).

Treatments of different types of music (electronic music, rock music, and classical music) promoted lettuce growth compared to no music, 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 and had the greatest impact (Wang, 2023).

[4] The term "hypocotyl" refers to the part of a seedling that constitutes the stem and is located between the first leaves and the root.

4.6.6 The preferred music by roses

An experiment with rose (*Rosa chinensis*) cuttings potted in substrate divided in to five groups with six plants in each group were exposed to four different music with one control group without music. The music was Indian classical music (Violin music of Raaga Sindhu Bhairavi), Vedic chants (Rig Veda), Western classical music (Pachelbel's Canon in D-Soothing) and Rock music (Hate Eternal "Bringer of Storms") for 60 minutes every morning for 62 days. There were daily measurements of the length of the shoot, the number of flowers were counted, the length of the internode[5] and the diameter of the flowers. It was observed that the plants exposed to Vedic chants showed the maximum elongation of shoot, maximum number of flowers and highest diameter of flowers. The internode elongation was highest in plants exposed to Indian classical music. The results indicate that subjecting the plants to Vedic chants or Indian classical music promotes the growth of plants as compared to the control group or subjecting them to Western classical or Rock music (Chivukula, 2014). No statistical model was presented so the conclusions is that the study is anecdotal and would be interesting to repeat in order to test if the hypotheses hold for a scientific analysis including standard deviation between the plants within the same treatment.

4.6.7 Peas and classical music

In a pot experiment on the crop cowpea (*Vigna unguiculata*) six different music styles were tested with four repetitions. The treatments were music within the genre of nature sounds, classic, traditional, techno, noise, and control with no music. As a result of playing classical music compared to control treatment (non-music), growth parameters increased; such as grain yield in single plant (33%), stomatal conductance[6] (21%), relative water content of leaf (21 percent), chlorophyll[7] (47 percent), leaf area of single plant (30%), plant height (38%), sub-branch (52%), gibberellin hormone[8] (81 percent), nitrogen (44%), and calcium (21%). However, some traits were reduced by playing classical music compared to control (non-music), that rate of their reduction for these traits was respectively: proline[9] (13%), abscisic acid hormone[10] (8%), and auxin hormone[11] (2%).The researchers conclude that as result of playing classical music, plant found better growth conditions, but playing traditional and techno music, and noise had negative impact on growth of cowpea plant (Alavijeh, 2016).

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[5] An internode is an interval or part between two nodes, such as those found on a plant stem. It's the stretch of stem between two points where leaves emerge.

[6] Stomatal conductance plays a central role in regulating the movement of carbon dioxide (CO_2) and water vapor between the atmosphere and the plant.

[7] Chlorophyll plays a vital role in the conversion of light energy into chemical bonds during the process of photosynthesis.

[8] Gibberellins are a group of plant hormones that play essential roles in growth and development. Gibberellins stimulate shoot elongation, allowing plants to grow taller.

[9] Proline is an organic acid classified as a proteinogenic amino acid. It plays a role in plant growth and differentiation across the plant's life cycle.

[10] Abscisic acid is a crucial plant hormone that plays a role in various developmental processes and responses to environmental stresses.

[11] Auxin is a group of plant hormones that play a crucial role in regulating growth and development.

5 Discussion and Conclusion

There are many exiting results from various studies, but there is a need for researchers to use a professional and transparent description of the details in the research methodology and the evaluation of the results. To gain detailed understanding of the mechanisms of both perception and crop response, an interdisciplinary research teams need to be composed of competence from acoustical ecology, auditory mechanics and plant physiology. It is not easy to separate real effects if there is a lack of description in the methodology and poor analytical data. Even so, it is shown that sound waves affect plants in different stages of their growth cycle. It is also clear that different species react diverse to different types of music or sounds. From an applicative point of view, in-depth knowledge of plant species sensitivity towards sound and music can be used to stimulate the biosynthesis of targeted secondary metabolites, and thereby obtaining bioactive enriched products with less hazardous chemical inputs, which can enhance sustainable natural environment.

The sound sensitivity of plants should make us aware that there is a risk that crops will behave differently also to traffic noise and that it might present a risk to plants in perceiving important environmental information. Noise pollution could therefore be a factor that should be considered both in ecological and agronomic settings.

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