EFFECTS OF SOUND FREQUENCY ON GERMINATION AND SEEDLING GROWTH OF CHILI (*Capsicum annuum)* SEEDS

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Optimization of crop productivity and sustainability should be achieved through optimization of seed germination and viability of seedlings. This study examined how certain sound frequencies affect the early development of Chili (*Capsicum annuum*) seeds to find eco-friendly, non-chemical methods for maximizing seedling vigour. In here, the effects of frequencies of sound such as 125 Hz, 250 Hz, and 500 Hz were used to check the germination and early growth of *Capsicum annuum* seeds as pertaining to identify the best frequency which encourage the seedling growth. The experiment was conducted under a controlled environment where seeds were exposed to single sound frequencies for four hours daily with constant environmental conditions along with two controls (ambient and no sound). Important growth characteristics like germination percentage, shoot and root length, seedling weight, and chlorophyll content were monitored on a 15-day regimen. Results indicated that at 250 Hz sound frequency, it showed the maximum germination percentage, shoot and root elongation, and seedling vigour, while 125 Hz caused an increase in the content of chlorophyll to the highest level. 500 Hz treatment caused variable effects and the control sound group never lived up to expectation. In addition to this, the development of fungi along with seedlings was affected due to treatments with sounds. According to this research, 250 Hz sound frequency was confirmed as the best sound frequency for promoting germination of *Capsicum annuum* seeds and development of seedlings. Seeds treated with this frequency showed more germination, shoot and root elongation, and chlorophyll content than controls involving no sound and ambient sound. These results show that the processing of sound frequency can be an environmentally friendly, chemical-free method for increasing crop yield.

Keywords: chili seeds, *Capsicum annuum*, seed germination, seedling growth, sound frequency, plant physiology, frequency-specific sound treatment

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Introduction

Seed germination and seedling development are also key phases that ascertain crop health and ecosystem well-being and depend, to a large extent, on physical environments such as water, heat, oxygen, and light to optimize plant growth (Bewley *et al*., 2013).Yet, initial evidence suggests that novel factors, such as sound waves, are also poised to have a key role in plant growth regulation (Hassanien *et al*., 2014).

Sound is a physical energy that propagates in the form of vibration. Plants do not possess any ear organs. Yet, they can sense and react to mechanical stimulus. It has been demonstrated in recent years that some frequency sound can induce physiological and biochemical responses in plants such as an alteration in hormone content, enzyme activity, and cell division rate. These reactions can result in seed germination, seedling vigour, and overall growth stimulation (Lee & Kim,2013). Even low-frequency sound waves have surprisingly been employed to positively stimulate plant growth, though very high or very low frequencies have fewer or even adverse effects (Jeong *et al*., 2008).

In this study, the effect of some low-frequency sound waves (125 Hz, 250 Hz, and 500 Hz) on the germination and seedling growth of chili (*Capsicum annuum*) is investigated. The objective of the study is to evaluate the effects of specific sound frequencies on the early growth and vigour of *Capsicum annuum* seedlings.

Methodology

Materials utilized in this study are one hundred and fifty MICH HY 01 chili (*Capsicum annuum*) seeds of the Hayleys brand; lids and glass jars for controlling the environment; sponges and clay for soundproofing material; speakers to subject the seeds to sound; a frequency generator to generate a specific frequency of sound; and a sound meter to measure precisely (Cai *et al*., 2014). Petri dishes, cotton wool, beakers, coco peat, and distilled water were also used. Measurements were taken with a measuring scale and a Soil Plant Analysis Development (SPAD) meter to measure the chlorophyll content.

Chili seeds (*Capsicum annuum*) were washed and subjected to imbibition in water for 10 hours and kept in five Petri dishes with thirty each, and after two days, distilled water (10ml) and cotton wool were added to maintain humidity. Glass containers covered in sponges and glued with clay were used to construct soundproof rooms (Memiş *et al*., 2022). Fixed frequencies (125 Hz, 250 Hz, and 500 Hz) were played at 80 decibels (Cai *et al*., 2014) through chargeable speakers (Yeoh *et al*., 2024). The chambers were assigned to prevent mistakes, and control groups were put in ambient and soundproof conditions (on average,80 Hz). Cross-contamination having been prevented, treatments of sound were separated and given for four hours per day (Yeoh *et al*., 2024). Germination percentage was recorded, and five well germinated seedlings were then shifted into five beakers of coco peat, one for each of the five treatment techniques. Shoot length, root length, seedling weight, and chlorophyll content were observed on each fourth day with the final observation done on day fifteen for analytical report, though the interval between the seedling phase and the reproductive phase in chili plants is approximately 45-60 days, as flowering and fruiting tend to begin at 60-75 days after sowing (Lee *et al*., 2023). One-way Analysis of Variance (ANOVA) was performed through Minitab software to find the statistical significance of the effect of sound frequency.

Results and Discussion

Figure 1 : The results indicate that those seeds exposed to the 250 Hz frequency had the greatest germination percentages during the observation period, followed by the No sound and 125 Hz groups. The 500 Hz and ambient controls had far lower percentages of germination.

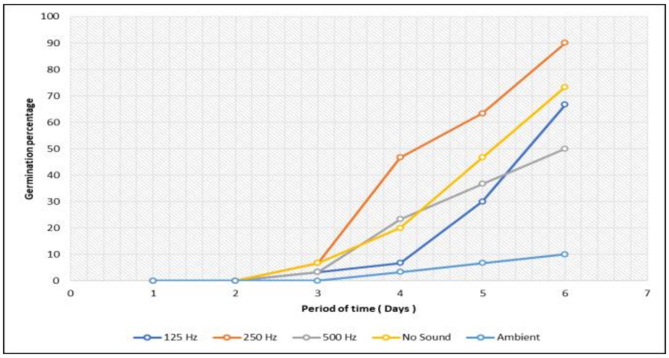

Figure 1: Seed germination percentage of chili seeds

Figure 2 : Seedlings treated with the 250 Hz sound frequency had the highest increase in fresh weight over time, followed by that of ambient and 125 Hz. No sound and 500 Hz treatments also had significantly lower fresh weights.
Figure 3 : SPAD readings for chlorophyll content and overall plant vigour were highest in 125 Hz and 500 Hz treatment seedlings, followed by the 250 Hz treatment. No sound and ambient groups again had lower SPAD values.

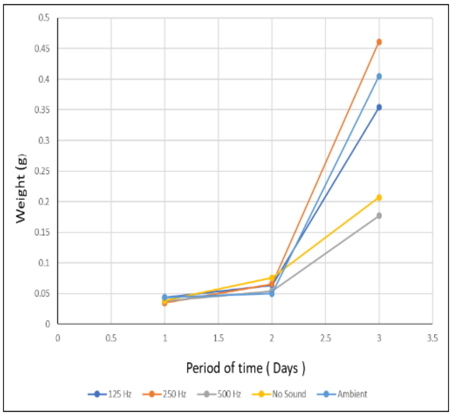

Figure 2: Fresh weight of the seedling

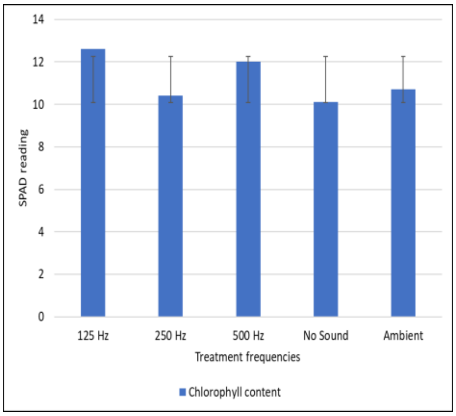

Figure 3: Chlorophyll content of the chili seedling leaves

Figure 4 : 250 Hz had the longest shoot lengths during the days measured, and the maximum growth per day on average. No sound and ambient groups had middle range shoot growth, and 500 Hz was the lowest in shoot growth than the 125 Hz group.

Figure 5 : The root length data also indicates that the seedlings in the 250 Hz frequency of sound recorded the highest growth, followed by No sound and 125 Hz treatment groups. The 500 Hz and ambient treatment groups were equally grown but comparatively less than the others in growth.

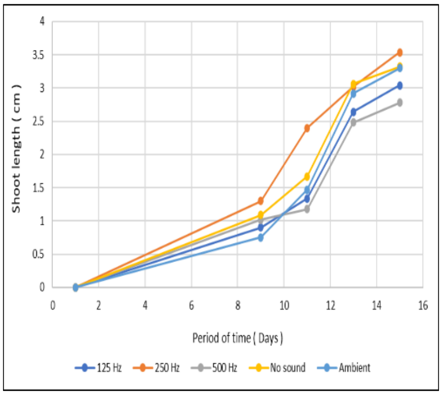

Figure 4: Shoot length of the seedling

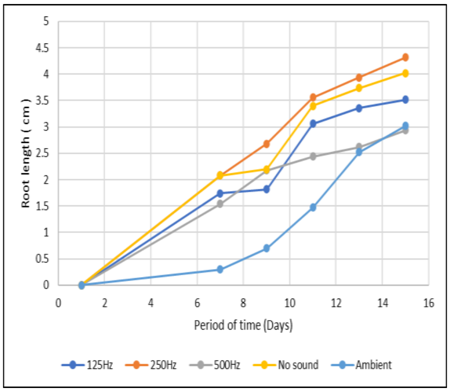

Figure 5: Root length of the seedling

This experiment tested the effect of different frequencies of sound (125 Hz, 250 Hz, 500 Hz) on germination and growth of chili seeds, and ambient noise and silence were used as controls. Sound with an intensity of 80 decibels was obtained from using audacity. Frequency in the ambient was constantly recorded and checked to have an average frequency of 80 Hz. ANOVA results indicated significant differences ($p < 0.05$) among treatments for germination percentage, shoot length, root length, and chlorophyll content. There were sound frequencies observed to induce seed germination and seedling growth parameters than the control treatment.

The optimal seed germination and seedling growth was 250 Hz frequency (Cai *et al*., 2014), and 125 Hz created the highest chlorophyll content and induction maximum photosynthesis. Seeds treated with ambient sound, nonetheless, possessed poorest dryness and moisture growth control, while chambers with control had higher humidity and growth. 500 Hz possessed mid-growth and lowest fresh weight. Fungal growth was worst under 500 Hz and most richest without sound, indicating sound influences on microbial growth. Fungal test ensured results to be a sound treatment effect and not an effect of contamination. Generally, there are some frequencies of sound that are effective to stimulate seed germination and seedling growth and provide a green agriculture approach.

Conclusions

250 Hz was identified by the study as the most suitable sound frequency for increasing *Capsicum annuum* seed germination and seedling growth, which increased all the major growth factors when compared to controls. It reflects that sound treatment is an environmentally friendly, chemical-free method of increasing crop yields.

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