ACOUSTICAL COMPLEXITY DEPENDENT RESPONSE OF PLANTS AND ANIMALS TO AUDIBLE SOUND STIMULI - A QUANTITATIVE CHAOS BASED ASSESSMENT

Thesis submitted by

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(Science)

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(Registration no: D-7/ISLM/39/17 dated 15.12.2017)

For the Degree of Doctor of Philosophy (Science)

Under Guidence of
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PROFORMA – 1

"Statement of Originality"

I ...Mousumi Das... registered on...Doctoral (PhD) programme under Faculty Council of Interdisciplinary studies, Law and Management (ISLM), Jadavpur University (Registration no: D-7/ISLM/39/17 dated 15.12.2017)... do hereby declare that this thesis entitled "ACOUSTICAL COMPLEXITY DEPENDENT RESPONSE OF PLANTS AND ANIMALS TO AUDIBLE SOUND STIMULI - A QUANTITATIVE CHAOS BASED ASSESSMENT" contains literature survey and original research work done by the undersigned candidate as part of Doctoral studies.

All information in this thesis have been obtained and presented in accordance with existing academic rules and ethical conduct. I declare that, as required by these rules and conduct, I have fully cited and referred all materials and results that are not original to this work.

I also declare that I have checked this thesis as per the "Policy on Anti Plagiarism, Jadavpur University, 2019", and the level of similarity as checked by iThenticate software is ...3...%.

Signature of Candidate: Mousumi Das.

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<u>**PROFORMA – 2**</u>

CERTIFICATE FROM T HE SUPERVISOR/S

This is to certify that the thesis entitled…"ACOUSTICAL COMPLEXITY DEPENDENT RESPONSE OF PLANTS AND ANIMALS TO AUDIBLE SOUND STIMULI - A QUANTITATIVE CHAOS BASED ASSESSMENT"… submitted by..Smt Mousumi Das.. who got her name registered on…15.12.2017..for the award of Ph. D. (Science) degree of Jadavpur University is absolutely based upon her own work under the supervision of …Dr. Dipak Ghosh, Emeritus Professor. Sir C.V. Raman Centre for Physics and Music, Jadavpur University… and that neither her thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.

Dipak Ghosh 25/7/2022

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PREFACE

Cognition of audible sound including music is a complex and vastly intricate process. Various effects of music have already been documented in plants and animals and it has been noticed that those effects are very much music as well as species specific. Despite having evidences regarding potential of different genre of music to influence plant and animal physiology, innovative interdisciplinary approaches are required to make substantial progress on this issue.

Now the question is can music be defined? Most of us agree that music is nothing but the art of arrangement of sound with styles specially improvising three fundamental bases of physics - frequency, amplitude and timbre, but in real life music is something much more than that. Music is a mode of communication between human beings as well as between other living creatures.

The physics of music is interesting because of its aesthetic beauty as well as its ability to convey a variety of moods through its rendition. Music signals are said to possess a chaotic but self-similar structure in different scales. At first sight music shows a complex behavior: at every instant components (in micro and macro scale: pitch, timbre, accent, duration, phrase, melody etc.) are close linked to each other. All these properties (above stated in a heuristic characterization) are peculiar of systems with chaotic, self-organized, and generally, nonlinear behavior. Therefore, the analysis of music using linear and deterministic frameworks seems not to be useful.

In recent years complex systems have been studied in different domains of sciences including economics and also humanities studies in general. In this respect music is also a complex system which evokes emotion or some effect in human which is also a complex system. Several approaches have been documented by different scientists for tackling complex systems. In this context chaos and fractals play a dominant role. Many researchers are also interested in studying fractal properties of plants and animals. Last decades have witnessed exhaustive research on effect of music on human beings acoustically and from neuroscience standpoint utilizing chaos based quantitative parameters.

The scenario of research on effect of music in plants and animals is still in its infancy. In the present investigation we have attempted to address the effect of music (a complex system) on plants and animals (also a complex system). The quantitative approach can justify whether music can be used as a stimuli for growth of plants and animals. The following are the details of enquiries which will address in the present research:

1. Does a frequency specific audio signal affect plant growth differently or in the same way in closely related different plant species?
2. Does music have any effect on germination kinetics and growth of plants and the effect is species specific or not? Further is there any correlation between different genres of music with germination and growth dependent parameters?

3. Auditory environmental enrichment through music does influence the physiology specially growth and stress level in fish? Additionally, the physiological responses are genre of music sensitive or not?
4. Our intention is to relate complexity of music with complexity of plant and animal growth from a new perspective choosing parameter as quantity which is emerged from the complex system. For different genres of music this parameter is Hurst exponent or DFA. For plants and animals these are germination percentage, mean germination time, growth in terms of stem length (in case of plant); and weight gain, specific growth rate, length gain, and plasma cortisol level (in case of animal).

Following standard protocol we have investigated a randomized control assessment on these parameters of plant and animal and tried to correlate them with complexity of music of different genre in terms of Hurst exponent or DFA. This is the objective of the present thesis using a novel technique not adopted so far.

It deserves mentioning that any genre of music is a complicated mixture of frequency and amplitude and therefore in terms of frequency only or with amplitude cannot provide the exact complexity of the music rigorously. However, we have included one section in the present investigation where effects of different frequency in two different plant species have been shown for comparison seek.

For studying acoustical complexity dependent response of plants and animals to audible sound stimuli, input of music signals serves the desired purpose.

OUTLINE OF THE THESIS

Chapter 1 presents general introduction discussing about acoustics, chaos theory, fractals and multifractals, Hurst exponent and Detrended Fluctuation Analysis. **Chapter 2** deals with review literature and objective of present research. **Chapter 3** presents the common methodologies used for this study - Randomised Control trial and Detrended Fluctuation Analysis of music signals. **Chapter 4** describes the selected genre of music used as stimuli along with selected plant and animal species. The effect of frequency-specific audible sound signals on *Pisum sativum* and *Cicer arietinum* plant growth are discussed in **Chapter 5**. **Chapter 6** and **Chapter 7** deals with the influence of different musical sound on seed germination kinetics and growth of *Pisum sativum* and *Cicer arietinum* plant respectively. **Chapter 8** presents the impact of different music stimuli on growth and stress physiology of Nile Tilapia (*Oreochromis niloticus*). **Chapter 9** discusses the conclusions drawn from our own investigations in summary form.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 ACOUSTICS

1.1.1 INTRODUCTION

Acoustics is a branch of physics which deals with all the mechanical waves in solids, liquids and gases including audible sound, infrasound, ultrasound and vibration. The fundamental properties of acoustics are production and transmission of sound including its biological and psychological effects. In modern society the application of acoustics is most obvious in music, architecture, medicine, audio and environmental noise control industries and many more.

1.1.2 EARLY RESEARCH IN ACOUSTICS

'Wheel of Acoustics' of Robert Bruce Lindsay is a popular overview in the field of acoustics (1). Pythagoras, an ancient Greek philosopher (6th century BC) observed that the lengths of string actually responsible for the production of harmonious sound remaining other factors equal. Aristotle (384–322 BC) worked on the propagation of sound wave. Vitruvius (20 BC), a Roman engineer and architect was the pioneer in architectural acoustics (2). Galileo Galilei (1564–1642) and Marin Mersenne (1588–1648) discovered independently the laws of vibrating strings that Pythagoras started 2000 years ago. It is noted that Galileo was the father of psychological and physiological acoustics. Mersenne did experiments for finding speed of sound in air. Newton in1687 created a landmark in physical acoustics deriving the relationship of wave velocity in solids (Principia, 1687).The eighteenth and nineteenth century was the era of mathematical acoustics. Helmholtz did a lot of works in this field.Lord Rayleigh is world famous for "The Theory of Sound" (3). Henry, Wheatstone and Ohm did monumental works in the field of acoustics and electricity. In the twentieth century the advancement of technological applications were dominated by the work of Sabine and other architects. Gradually with the advancement of science telephone made a global transformation. In medicine ultrasonic frequency added a new level of sophistication.

1.1.3 FUNDAMENTAL CONCEPT OF ACOUSTICS

Acoustics deals with generation of vibrations and mechanical waves, their propagation and also reception or transduction into other form. Among the steps sound propagation is the central one. Sound propagates mainly as pressure wave in fluids (water and air) and as mechanical wave in solids like longitudinal, transverse and surface waves. Sound travels undistorted with some delay in time and travels independently irrespective of sources. The ambient pressure disturbances create different sound pressure (field quantity) level and are measured as decibels. The number of vibrations or waves that undergo per unit of time is the sound frequency and is denoted by Hz. Sound frequency less than 20 Hz is known as infrasound and greater than 20 kHz is ultrasound. Both infra sound and ultra sounds are used as therapeutic and diagnostic tools like ultrasonography and elastography. The sound frequency range in between this two is audible sound which we can hear. Music and speech communications are applied field of audible sound range. With the help of different analytic instruments like spectrum analyzer, we can visualize and measure acoustic signals with their properties.

1.1.4 MUSICAL ACOUSTICS

Musical acoustics is a branch of acoustics deals with the physics of music. It concerned with how sounds are employed to make music mainly the processing of audio signal, the analysis of music composition and perception and neurocognition of music. Musical sound is nothing but the regular or periodic vibrations of sound with a definite pitch combined with loudness, timbre and duration. Frequency is the principal determinant of perceived pitch. The frequency at which the entire sound wave vibrates is the fundamental. The other sinusoidal components of frequencies above the fundamental are overtones. The fundamental, overtones and the other frequency components form total waveform and are called partials. They together form the harmonic series. Harmonics are the overtones which are perfect integer multiples of the fundamental. For example, a note with a fundamental frequency of 200Hz has harmonics at (200,) 400, 600, 800, 1000 and so on. Scale of music is the material of composition taken from the collection of pitches. The diatonic scale consists of seven tones in each octave. Timbre is quality of the note that is the amplitudes of the overtones relative to the fundamental.

Music is created in vocal and instruments by forming standing waves. Standing waves result when two waves of equal frequency and wavelength moves through a medium, reinforce each other perfectly. In all elastic media we can find standing waves. Guitar strings, air column in flute, skin of the drumhead, etc. can create standing waves. When a note is played in a musical instrument, the medium vibrates and due to that sound is produced. It has discussed earlier that fundamental frequency along with its all overtones together form the sound of yearning musical note.

1.1.5 MUSIC AS COMPLEX DYNAMICAL SYSTEM

Musical acoustics is basically a complex dynamical system. Recent investigations have convinced that complex systems are responsible for producing various dynamical systems-from brain to physiology, from music to visual art, for all geological systems and even in stock markets. Since music is essentially complex dynamical system, recent years have witnessed a plethora of work on study of musical acoustics using various adequate parameters. Among various methods chaos theory can claim its predominance over others. The following section presents a more elaborate account of the origin and essentials of chaos theory.

1.1.5.1 CHAOS THEORY

Chaos is the science of surprise which explains how to expect the unexpected. While most traditional science deals with allegedly predictable phenomena, chaos theory handles nonlinear unpredictable things of the universe. The chaos theory can be well explained by butterfly effect established by Edward Lorenz (1961) during his work on weather prediction. He showed that initial small changes can cause huge changes in long-term weather prediction (4) and this was beautifully justified with the help of statement like “Butterfly flapping its wings in Brazil can cause a hurricane in Texas”. That means how an initial very small change in a system can cause large differences later through a chain of events. Actually these events make the system unpredictable for large-scale phenomena. Not only weather, seismic data (5), foreign exchange market (6), internet traffic (7) and other natural systems (8) also follow the chaotic behaviour and can be studied by fractal mathematics. Chaos theory also reveals that chaotic system is a complex, apparently random system underlying different patterns, self-similarity, feedback loops, repetition, self-organization and fractals. Fractal has a special relevance in chaos theory, because fractals are the geometry of chaos. The graphs of most chaotic systems are fractals (9). It is also well known that chaos is interrelated with nonlinear systems; and nonlinearity is an inevitable condition for chaos. In a nonlinear system the output changes is not proportional to the input changes (10, 11). Most of the systems in nature are inherently nonlinear (12) and for this it is very much interesting to physicists (13, 14) and biologists (15, 16, 17). In this aspect, fractal and multifractal techniques are assuming great importance to assess a number of nonlinear biological and physiological systems.

1.1.5.2 FRACTALS AND MULTIFRACTALS

In 1975 mathematician Benoit Mandelbrot first used the term fractal describing geometric patterns in nature (18, 19). According to Mandelbrot, fractal is such a geometric shape which can be split into parts and each part is (at least approximately) a reduced –size copy of the whole. Fractals are self-similar (10) and also a never ending infinitely complex pattern. Fractals are independent of scales or fractal dimension. The nature surrounding us is full of fractals and we are very much familiar with these patterns. For example, mountains, rivers, coastlines, clouds, waterfalls etc. The structures of all of nature's plants and animals are fractals (Fig.1.1). The branches of tree from trunk to the tip, the roots, the leaves, the flowers and fruits all are fractal structures.Fractals are super-efficient in constructions of the parts of plants, maximizing their exposure to sunlight and efficient enough to transport nutrients throughout the cellular structures. Here we can see a blending of physical and mathematical fractal patterns of growth. Human brain, kidney, lung, circulatory system, liver, pancreas –also are fractal structures. On the contrary, multifractal is a set of interlaced fractals.

Fig.1.1 Fractal structures: a. Trees b. Human brain

(Source: unsplash.com)

Multifractal shows scale dependent self-similarity. Naturally evolving phenomena are hardly ever characterised by single scaling ratio; rather different scaling patterns are observed over different parts of a whole system. That is, no uniform clustering pattern is constructed over the whole system.

To quantify a complex musical signal neither frequency nor amplitude alone can be used as a parameter for describing the system. Hence we have used a nonlinear chaos based parameter for characterizing samples of different genres of music.

Standard parameters like Hurst exponent analysis or DFA has been selected for proper assessment for characterizing music samples.

1.2 HURST EXPONENT AND DETRENDED FLUCTUATION ANALYSIS

1.2.1 HURST EXPONENT

Hurst exponent is used to measure the long term memory of a particular time series. It is generally referred to as index of long range dependence. Originally this exponent was developed in hydrology for determining the optimum dam size over the Nile River after observing the drought and rain conditions of the river for a long period (20, 21). The term Hurst Exponent was derived from the name of scientist Harold Edwin Hurst who was pioneer in this field. The exponent is denoted by H in fractal geometry and is directly related to D, which is fractal dimension. The value of H ranges from 0 to 1. The value range 0.5 -1 indicates a long term positive autocorrelation. When H is equals to 0.5, it indicates an uncorrelated series. 0-0.5 value range indicates a long term switching of time series between low and high values. So the higher values indicate a less roughness, less volatility and a smoother trend (22). There are different estimators of long range dependence. The best known oldest one is rescaled range analysis proposed by Mandelbrot and Wallis (23, 24). Other alternatives are Periodogram regression

(25), local Whittle's estimator (26), aggregated variances (27), wavelet analysis (28, 29) and DFA. Mathematically the Hurst exponent can be estimated in the following way (30, 31). Here H is replaced by generalised form of the exponent H_q.

$$H_q = H(q),$$

for a time series

$$g(t)\ (t = 1, 2, ...)$$

also be defined by the scaling properties of its structure functions S_q(T):

$$S_q = [\,|g(t+T) - g(t)|^q\,]_t \sim T^{q\,H(q)},$$

where $q > 0$, T is the time lag and averaging is over the time window

t >>T, the largest time scale of the system.

1.2.2 DETRENDED FLUCTUATION ANALYSIS

In time series analysis, chaos theory and stochastic processes, detrended fluctuation analysis method is used to determine the self- affinity of a signal. DFA method is also used for the analysis and elimination of trends from data sets. In 1994 DFA was first used by Peng to determine the long range correlations present in DNA nucleotides (32).

DFA fora time series say {t1; t2; t3::::::tn} can be computed by following:

1. Another series T as [T(1);T(2);T(3)......T(N)],

   $T(k)=\sum_{i=1}^{k}(t_i - t_{mean})$. t_{mean} denotes mean of the points in the series t.
2. The series T is under interest. Series T is sliced into threads of length N. Each thread must contain this same number of element which is N. For each of the N element thread, a line is fit which signifies the trend in the thread. The fit is called Tn(k).

3. The detrending is $[T(k) - T_n(k)]^2$ which helps in calculation of RMS fluctuation.

F(N)= $\sqrt[2]{\frac{1}{n}\sum_{k=1}^{n}[T(k) - T_n(k)]^2}$ is called root mean square fluctuation.

4. F(n)$\propto$ n^{α}, a is expressed as the slope of logarithimic plot of log[F(n)] versus log(n).

Obtained α is the DFA value of a signal. It is called the DFA scaling exponent or the conventional Hurst Exponent (H) and it quantifies self-similarity and correlation properties of time series. As it suggests, a time series having higher DFA scaling exponent is a symbolic quantification of presence of long range correlation. If we construct a log-log graph plotting F(n) against n, a straight line is obtained which indicates the statistical self-affinity and α (the scaling exponent) value is the slope of the straight line of the graph.

Detrended fluctuation analysis has become a widely used technique for the determination of (mono-) fractal scaling properties and the detection of long-range correlations in noisy, non-stationary time series (33, 34). DFA has successfully been applied to diverse fields such as DNA sequences (35, 36), climate (37), EEG data (38), economical time series (39), speech pathology detection (40), neural oscillations (41) etc. Music time series signals are non-stationary in nature and the methods like DFA is also very useful in this case also. This technique has also been used to study the scaling behavior of the fluctuations in the music signal (42, 43, 44, 45). The utility of using this technique is that we can classify the genre of musical stimuli with the help of a single DFA scaling exponent 'α' which gives an estimate of the amount of long-range correlations (LRTC) present in the time series data.

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CHAPTER 2

REVIEW OF EXISTING RESEARCH AND OBJECTIVE OF PRESENT STUDY

2.1 EFFECT OF AUDIO SIGNAL INCLUDING PLANT ACOUSTIC FREQUENY TECHNOLOGY (PAFT) ON DIFFERENT STAGES OF PLANT LIFE CYCLE

It is well known from the work of Sir Jagadis Chandra Bose (1, 2), an eminent plant physiologist and physicist that plants react to the attitude with which they were nurtured and plants are sensitive to external environmental factors like light, cold, heat, sound etc. It has already been discussed that sound is one kind of acoustics energy. Sound frequency less than 20 Hz is known as infrasound and greater than 20 kHz is ultrasound. The sound frequency range in between this two is audible sound and also includes music. Studies have investigated that audible sound wave including music can influence different stages of plant life cycle. Plants also make sound spontaneously and even emit sound from their xylem which is a water transporting system. Tension and cavitation produced in the xylem vessels during transpiration along with decreased diameter of xylem vessels are probable causes of generation and emission of sounds in plants (3, 4, 5, 6).

Seeds are very much essential in rebuilding the productivity of a crop. During seed germination sound energy directly affect hormonal changes, enzyme activation and various other metabolic activities. Sound waves with different frequencies, intensities and amplitudes affect plant growth differently in different plant species. Studies have shown that sound vibration could stimulate a seed or plant (7). Sound treatment with different frequencies and intensities, particularly wave of 5 kHz with 92 dB enhanced tiller growth including number of roots and plant dry weight in Rideau wheat seedlings (8). Investigating the biological effect of sound stimulation on *Oryza sativa*, scientists revealed that sound frequency of 0.4 kHz with SPL of 106 dB significantly increased the germination index, fresh weight, shoot length, cell membrane permeability and activity of root system. Sound stimulation exceeding 4 kHz and 111 dB had negative impact on growth of *Oryza sativa* (9). Young *Zea mays* root tips showed bending pattern towards continuous sound stimuli and best response was measured between 0.2 and 0.3 kHz (10). Scientists also revealed that sound wave with 1000Hz and 100dB increased the germination rate along with reduced germination time in *Echinacea angustifolia* (11). Mathematical model was also proposed by scientist (12) to describe the isothermal seed germination rate as a function of time with varying sound frequencies and intensities in barley. Sound frequency of 50 Hz had positive effects on seed germination in *Oryza sativa and Cucumis sativa.* (13). Germination rate of *Arabidopsis thaliana* was improved by treatment with sound frequency above 70 Hz with 0.42 mm amplitude (14). It has been reported that audible sound with specific range of frequencies (1000-1500 Hz, 1500-2000 Hz, and 2000-2500 Hz) and intensities (80 dB, 90 dB, and 100 dB) had different effects on mung been (*Vigna radiate*) germination and growth . Significant reduction in germination time and as well as enhanced plant growth were noticed after treatment with frequency around 2000 Hz and intensity around 90 dB (15).

A lot of researches have been done on *Actinidia*, *Dendrobium candidum* Wall. ex Lindland *Chrysanthemum* callus. *Actinidia chinensis* (Kiwi) is one of the extensively used medicinal plant rich in sugar and vitamins (16). It was found that sound stimulation accelerated the root activity in *Actinidia chinensis* including increased number of roots and total length but retarded the cell membrane permeability (17). It was also reported that sound stimulation of 1 kHz with 100 dB intensity has increased the ATP content, Superoxide dismutase (SOD) and soluble protein contents in *Actinidia chinensis* but these activities decreased when sound stimulation exceeds the above mentioned frequency and intensity (18, 19). Superoxide dismutase is an important antioxidant of nearly all cells and helps in defence mechanism by protecting internal organelles during oxygen exposure (20, 21, 22). *Dendrobium candidum* Wall.ex Lindl is a precious Chinese medicinal herbal plant used to treat eye diseases, removing toxins from human body and also have other immunomodulatory effects (23, 24). The aerial parts of *Dendrobium* are mainly used for medicinal purposes (25). There is report showing the increased activities of antioxidative enzymes in different parts (shoots, roots and leaves) of *Dendrobium candidum* Wall. ex Lindl under exposure to sound vibration. It may be due to accumulation of active oxygen species in those plant organelles during early hours of treatment (26). *Chrysanthemum* is also a worldwide used medicinal herbal plant (27, 28). Studies have shown that sound stimuli could influence the growth rate of *chrysanthemum* callus by affecting the cell wall calcium (29). Sound frequency of 1000 Hz with 100dB intensity enhanced root metabolism and growth in *Chrysanthemum* including increased soluble sugar contents with higher amylase and protein activities (30). Playing appropriate sound by using sound stimulation generator has enhanced the level of soluble proteins and superoxide dismutase activity along with increased rate of calcium absorption by *Chrysanthemum* callus. Sound wave exceeding 0.8 kHz and intensity of 100 dB had negative impact on the above indexes. Surprisingly the activity of Indole-3-acetic acid (IAA) oxidase was reversed when compared to the above mentioned indexes (31). Sound wave stimulation also accelerated the synthesis of nucleic acid and protein in *Chrysanthemum* (32). Understanding the effect of sound stimulation on plasmalemma ultrastructure of *Chrysanthemum* roots, scientists have found enhanced lipid fluidity in the cell wall as well as in the plasmalemma and decreased thermodynamic phase transition temperature which leads to faster growth and division. The secondary protein structure of plasmalemma and cell membrane electric potential were also influence by sound wave stimulation. Being the most important and sensitive outermost portion of cell, Plasmalemma plays a crucial role in signal transduction from outside environment to the interior of the cell. Many substances including protein and membrane lipids reside in the plasmalemma which actually helps in the signalling processes (33). Sound wave stimulation enhanced the growth of *Chrysanthemum* by changing the cell cycle mainly by increasing the number of cells in the S phase and decreasing the number of cells in the G_0/G_1 phase (34). *Gerbera jamesonii*, the seedlings of *Chrysanthemum* has showed increased root activity and enhanced soluble protein content under sound stimulation. Sound stimulation also sensitized the plasma membrane H^+ ATPase to Ca^{2+}. It is also elucidated that PM H^+ ATPase could regulate the growth and development by interacting with environmental factors. Additionally, sound exposure enhanced the activities of POD isoenzymes and protective enzymes. Under sound stimulation, probably phosphorylation and dephosphorylation processes regulate the plasmalemma H^+-ATPase activity (35, 36). Studies have shown that plasma membrane H^+ ATPase activity has enhanced by sound wave stimulation in *Chrysanthemum* callus probably due to Ca^{2+} dependent phosphorylation. Illustrating the effect of sound stimulation on *Chrysanthemum* callus plasma, a very high significant difference has been observed in K^+ channel permeability. Sound stimulation enhanced the K^+ channel opening frequency by 50% when compared to control (37, 38). Report also demonstrated that ca^{2+} dependent protein kinase plays a crucial role in transducing the sound signal to the PM H^+ ATPase in *Chrysanthemum* callus and triggered the cell to response accordingly (39). Studies also indicated that under sound stimulation the level of RNA synthesis and amount of soluble protein had also increased (40). Indole-3-acetic acid or IAA is one of the most important auxin produced in the apical portion of shoot and younger leaves of plants and helps in plant growth and development (41, 42). Abscisic acid or ABA is a plant stress hormone accumulated under stress condition (43, 44). Reports demonstrated that exposing *Chrysanthemum* callus to a particular sound stimulation (frequency of 1.4 kHz and intensity 95 dB) significantly increased the levels of Indole-3-acetic acid and decreased the levels of Abscisic acid when compared to control. These changes subsequently help in callus development and maturation. Signal generated by sound wave might activates specific gene and simultaneously regulate the levels of Indole-3-acetic acid and Abscisic acid in the experimented callus (45). Sound stimulation also had positive effects on cell membrane deformability (46). Reports pointed out that the concentration of ca^{2+} was higher in cytoplasm, nucleus and vacuole membrane and lesser in the vacuoles of sound wave stimulated *Chrysanthemum* callus. On the contrary the concentration of ca^{2+} was higher in vacuole and lesser in organelles of control group. Thus, by inducing different signalling pathways, concentration of ca^{2+} plays a major role in *Chrysanthemum* callus tissue growth (47). Beside these, ca^{2+} also keeps the cell membrane binding proteins in stable conditions and regulates the growth and homeostasis in plant cell (48). Research demonstrated that *Oryza sativa* exposed to sound wave of 0.125 kHz and 0.250 kHz showed significant increase in Ald (fructose 1,6-bisphosphate aldolase) mRNA expression, in contrast treatment with 0.050 kHz has showed significant decrease in Ald mRNA expression (49). Researchers also have investigated sound wave induced increased expression of TCHs genes encoding calmodulin-related proteins and xyloglucan endotransglycosylase / hydrolase in *Arabidopsis* (50). Investigating the effects of sound wave on protein structure in *tobacco*, scientists pointed out that 0.4 kHz sound frequency with 90 dB SPL influenced the secondary protein structure of the plasma membrane by increasing the α-helix and a decreasing the β-turn. These structural changes could increase the plasma membrane fluidity. The rate of cell growth and phase transition temperature slowed down significantly under sound treatment (51, 52). Sounds of varying frequencies and intensities could also change the secondary structure of cell wall proteins by altering the amide I and II bonds in tobacco (53). Sound stimulation accelerated the cell division and cell metabolism by forming increased amount of sugar and soluble protein in the cytoplasm of *D. morifolium* callus when exposed to frequency of 1 kHz with100 dB intensity (54). Sound frequency administered at a SF of0.4 kHz showed improved growth and propagation in *Chlorella Pyrenoidosa*. Audio treatment also evoked various kinds of biological responses including early maturity, delayed picking period and increased mycelium growth. Sound waves also accelerated the fruit size (2.4-43.3%) and yield (8.0-15.8%) in edible mushrooms (55, 56). It has been shown that sound wave of varying frequencies could influence the impatiens and bean plants. When the wavelength of pure tone sound coincides with the average of major leaf dimensions, maximum plant growth occurred (57). Reports pointed out that polyamines play a major role in normal plant developmental processes such as cell growth, cell division, organ development, flowering, fruiting, ripening and embryogenesis (58, 59). Sound wave exposure has also made plants more defensive against *Pieris rapae* caterpillar. The treated plants exhibited higher amounts of anthocyanin and glucosinolate compared to untreated control (60). Studies pointed out that sound treatment upregulated a number of genes including the mechanostimulus responsive genes, redox homeostasis genes, defence related genes, biosynthesis related genes, signalling related genes and transcription factors encoding genes in *Arabidopsis thaliana*. Sound wave stimulation with 0.5 kHz and 80 dB had showed maximum impact on phytohormones. Significant changes in the production of gibberellin (GA), indole- 3-acetic acid (IAA), jasmonic acid (JA) and salicylic acid (SA) were also noted (61). Gibberellin and indole- 3-acetic acid are growth related hormones, whereas salicylic acid and jasmonic acid are defence related hormones in plants. Report showed that sound vibration of 1000 Hz with 100 dB enhanced the maximum disease resistance capacity both in whole plants and detached leaves of *Arabidopsis thaliana* against *Botrytis cinerea* infection. Corroboratively, during the infection period an elevated level of salicylic acid (SA) and demoted level of jasmonic acid (JA) were also found in treated plants compared to that of control (62). *Arabidopsis* exposed to sound waves either of 250 Hz or 500 Hz has enhanced the expression of photosynthesis related proteins (63). *Solanum lycopersicum* (Tomato plant) is one of the most consumed and antioxidant rich vegetable source. Plants exposed to1600Hz and 90 dB showed best results in tomato fruit with increased contents of vitamin C, lycopene, total sugar, total phenol and total acid. Sound wave has also accelerated the accumulation of metabolites in tomato giving rise to improved fruit quality (64). Sound wave stimulation with 1 kHz delayed the ripening procedure by negatively regulating the following genes -ACS2, ACS4, ACO1, E4, E8,IN,TAGL1, HB-1, NOR, and CNR in tomato and made them firm. Sound treatment also affected some transcription factors facilitating the fruit ripening process (65, 66). Random noise exposure also could reduce the plant growth. Study has been done to observe the effects of random noise on coleus plant growth and result showed that sound affects the rate of transpiration which in turn affects plant growth (67). Playing high frequency loud pure tones to alyssum seeds, an increased rate of germination and growth has been observed whereas random noise showed an opposite results (68). Random noise also had detrimental effect on growth rate of tobacco plants (69). Audible sound also enhanced the growth and biomass production in cells of *Picochlorum oklahomensis* (70). Sound stimulation influences plant tolerance to abiotic stresses as well. For example, one hour sound exposure of 800-15000 Hz enhanced drought tolerance in rice including higher water contents and increased conductance of stomata (71). Sound of bee buzzing facilitated the pollination of flowers by inducing pollen release from anthers (72). Therefore bee buzzing served as beneficial signals to plants.

Plant Acoustic Frequency Technology or PAFT is used to treat plants with an intermittent pulse of sound frequency with specific intensity. By applying PAFT treatment a significant increase in biological responses have been found in cotton plants including seedling height, leaf width, single boll weight, boll numbers, number of boll bearing branches and yields. All these effects were very much frequency, intensity, distance and direction of sound dependent (73).The yield of paddy and wheat were increased qualitatively and quantitavely when exposed to PAFT generator. A significant increase in protein content of rice and protein, fat and starch contents of wheat were observed. This technology also made plants more insect pest and disease resistance by strengthening the immune systems. A 50% reduction in rice sheath blight disease was also noticed. In addition, three years experimental results revealed that PAFT could reduce the use of fertilizer by an amount of about 25% when applied in rice field (74, 75). Investigating the effects of PAFT on vegetables, scientists revealed an improved production of endogenous hormones including ZR, GA and IAA in eggplant, muskmelon, cowpea, tomato, and cucumber (76, 77, 78). Scientists have also investigated the effect of PAFT on cucumbers, strawberries, and tomatoes and observed that with increasing number of flower and fruits, other biological changes like chlorophyll content, photosynthetic activity, non-photochemical quenching and PS II photochemical efficiency were increased significantly in greenhouses (79, 80, 81, 82). The PAFT treated strawberries were grown stronger with greener leaves. The blossoming, fruiting and rate of photosynthesis were also accelerated significantly with an enhanced insect pests resistance and disease resistance capacity (83). The application of PAFT in greenhouses also enhanced yield of cucumber, tomato and sweet pepper with increased disease resistance capacity. It was noticed that viral and late blight diseases decreased in greenhouse tomatoes along with reduced aphids, mites and gray mold attacks (84, 85, 86).

Agri- wave technology which is nothing but applying PAFT technology with spraying of microelement fertilizer also has been applied on plants for enhancing the yield both qualitatively and quantitavely. This technology significantly enhanced the growth of tomatoes, promoted the ripening process and also increased the yield qualitatively and quantitavely (87). Spinach and lettuce has showed similar results of enhancement in growth rate and yield when treated with Agri- wave technology. An increased amount of vitamins A, B, C and sugar contents were also found in treated plant species. Further, the agri-wave technology has increased the disease resistant properties of spinach (88).

2.2 EFFECT OF MUSIC ON DIFFERENT PLANT SPECIES

Music is made up of sound waves with various frequencies and intensities and mathematically music is ordered. Researchers have investigated the effect of music on plant growth and plants provided with certain melodies showed a better growth than control (89). Ponniah and Singh (1955) were two of the pioneers in this kind of work. As a source of music they played violin pieces to plants for observing plant growth (90, 91). Musical sound significantly accelerated the germination rate in okra and zucchini seeds when compared to untreated control and noise (92). It has been investigated that long term exposure to powerful beating of heavy metals and rock music had detrimental effects on plants. In contrast, light and soft music with gentle vibrations accelerated plant growth with increased yield and also made plants stronger (93). Studies have shown that music treated plant produced thicker and greener stems and sprouted faster than control (94). Music exposure has been shown to improve quality and yield in barley, tomato and other vegetables (95, 96, 97). It is also reported that musical sound of different kinds has positive effects on root elongation as well as on cell metabolism (98). Report also pointed out that classical music treated plants have shown highest growth result than that of the untreated control (99). Rhythmic music, one classical and another with dynamically changing lyrics has increased the onion root tips elongation by enhancing mitotic cell division during germination (100). In another experiment *Rosa chinensis* plants were divided into five groups, one group was used as control group and rest were exposed to four different kinds of music including Indian Classical, Vedic chants, Rock, and Western Classical music. It has been found that plants exposed to Indian Classical music and Vedic chants exhibited promoted plant growth when compared to Rock music treated group, Western Classical music treated group as well as control group (101). Studies have revealed that classical music with natural sounds (green music) enhanced the polyamine levels and speeded up the oxygen uptake capacity in seedlings and mature plants (102). Playing rhythmic soft-melodious music has been found to stimulate growth and development in eight different medicinal and ornamental plants (*Tagetes erecta, Catharanthus roseus, Trachyspermum ammi, Duranta repens, Hibiscus rosa-sinensis, Epipremnum aureum, Dendranthema grandiflorm, Ocimum sanctum*) including increased height, increased number of leaves and flowers, advanced flowering tine and enhanced level of various metabolites including elevated levels of starch and chlorophyll (103). Researchers have investigated the positive impact of Indian classical raga on overall protein production in paddy, wheat, soya, horse gram and spinach plants (104). Studies have shown that light Indian music and Meditation Music could increase the height of stem and length of leaves in marigold plant along with higher number of buds and flowers whereas noise treatment had negative impacts on the above attributes. Exposure to Indian light music also showed faster sprouting and enhanced growth development in chickpea (*Cicer arietinum*) compared to untreated control (105). Classical music and rhythmic rock music had positive effects and non-rhythmic traffic noise has negative effects on number of germinated seeds, height of plants and number of leaves in *Cyamopsis Tetragonoloba* (common guar or cluster bean) as compared to control (106) . Playing rhythmic violin music and non-rhythmic traffic noise to *Phaseolus vulgaris* (common bean plant) scientists investigated that both music and noise had positive effects on plant growth as compared to control. Rhythmic violin music treated plants showed better growth than the non-rhythmic traffic noise (107). Investigating the biological effects of classical music and rock music on *Triticum aestivum* (wheat) plant growth, scientists observed that plants grew well with brighter green leaves when exposed to classical music than either the control or exposed to rock music (108). A study conducted on the effect of folk music played from wind instruments flute and pipe flute has revealed that the music produced by these instruments increased the average weight and yield outputs in apple tree and salad plants(109). Exposure to Sanskrit sholkas (Vedic Chants) enhanced shoot elongation and produced healthier *Vigna radiate* plants. On the contrary discouraging words had negative impact on plant growth and quality (110). *Ocimum sanctum* (*Tulasi*) plants subjected to Gayatri mantra, Solanum indicum plants exposed to Om Rsi Kesavaaya Namah mantra and Tylopphora indica climbers charged with Om Anantaya Namah mantra had showed increased growth along with enhanced efficacy in curing diseases (111). Playing Western pop music and Buddhist *pirith* chanting to *Codariocalyx motorius*, scientists have been found discernible effect of Buddhist *pirith* chanting on plant height, number of leaves, chlorophyll content, leaflt length, leaf width and leaf area; indicating improved growth performance when compared to Western pop music and control (112). It has also been reported that Agnihotra which is a Vedic ritual of chanting of mantras with offerings of brown rice mixed with cow ghee to the fire, enhanced stem length and root length in *Vigna radiate* (moong) 38% and 31% respectively than the untreated control (113). Agnihotra also accelerated the germination rate in rice seeds and also demonstrated increased growth rate in rice seedlings (114). Sindhu bhairavi classical raga exposed *Oryza sativa* (paddy), *Triticum asteivum* (wheat), *Spinacia oleracea* (palak), *Glycine max* (soya) and *Macrotyloma uniflorum* (horse gram) plants exhibited better overall plant protein productions when compared to control, Kapi and Desh ragas respectively (115).

Summing up all the above scientific observations, it can be concluded that audible sound with specific frequencies and intensities facilitated different stages of plant life cycle mainly germination and growth. On the other hand, various audio frequencies also had negative impact on plant growth. Quite different observations were noted in this domain with music. For example, both classical music and rhythmic rock music had positive effects on seed germination and plant growth including number of leaves in common guar or cluster bean (*Cyamopsis Tetragonoloba*) than the control plants (106). A contrasting observation (101) was noted where rock music had detrimental effects on rose (*Rosa chinensis*) plant growth. Growth parameters like shoot and internode elongation, number of flowers and diameter of flowers were decreased compared to the control plants. Interestingly, rock music induced plants were the first to sprout thorns and exhibited consistently higher number and density of thorns on the plants as compared to the other plants.

Although contrasting observations have been reported in rigor to genre dependence of plant growth and also as plant growth depends on species of different types, a careful observation may reveal the following thing –

1. The genre of music should be identified in the perspective of complex dynamical systems using appropriate parameters.

2. The process of germination in terms of Germination Percentage and Mean Germination Time for different types of plants should be addressed for different genre of music.

3. In a similar way the genre dependence of plant growth should be addressed using a suitable parameter for example stem length.

4. No such systematic and rigorous study considering the above mentioned critical points has been reported in literature till today.

5. The present investigation is done addressing all relevant parameters with preciseness. This is the novelty of the present dissertation.

2.3 IMPACT OF AUDIO SIGNAL INCLUDING MUSIC ON FISH

Production and perception of audio signal is common in fish like other vertebrates. Studies have shown that fish can generate acoustic signals for intraspecific communication mainly for survival and reproductive success (116, 117, 118). Swim bladder, sonic muscles, stridulating bones and other sonic mechanisms are mainly responsible for sound production in fish. Fish also responds to sound signals of the surrounding environments and able to detect directions of sound sources (119, 120). Fish even can discriminate and analyse sound of different frequencies and intensities (121). Unlike other communications, sound provides a long distance communication even in poor visibility areas. Scientists have investigated the effect of sound signals - music as well as noise on fish.

2.3.1 SOUND PRODUCTION IN FISH BY SWIM BLADDER, SONIC MUSCLES, STRIDULATING BONES, AND SOME OTHER MECHANISMS

The swim bladder which regulates buoyancy is also responsible for sound production in many fish (122, 123). The contractions of intrinsic or extrinsic muscles on and around the swim bladder change the volume of the bladder which leads to sound production in some fish (124). All deep sea fish produce tonal or pulsed sound with the help of sonic muscles. Few acoustical studies have been done on *Opsanus beta*, *Opsanus tau*, *Opsanus phobetron*, *Porichthys notatus*, *Ophidion marginatum* (125, 126, 127). Sonic fish without swim bladder muscles produce sound by stridulating bones. Sound production by grinding of pharyngeal jaws has been found in Grunts and by stridulating of pectoral fins has been revealed in croaking gourami (*Trichopsis vittatus*) and Pimelodid catfishes (128, 129, 130, 131, 132). Goby (*Bathygobius soporator*) produces sound by forcefully ejecting water through the gills (133). Within the audible range of <40 Hz to >1 KHz sound production by otolith organs namely saccule, lagena, and utricle with auditory filters have also been reported in some fish species (121).

2.3.2 EFFECT OF SOUND EXPOSURES ON FISH

Fish health and welfare very much depends on surrounding environmental conditions. Studies have shown that environmental enrichment with music improves fish welfare. On the other hand noise has the potential to do significant harmful consequences in fish. Reports pointed out that music could promote fish growth and also acts as stress remover in aquatic environments (134, 135). Different tempos of music namely slow tempo, medium tempo and fast tempo music was used to observe feeding parameters and thereby fish growth and body chemical compositions in turbot (*Psetta maeotica*). It was shown that slow tempo music had a positive effect on fish growth in terms of average fish weight, relative and specific growth rate whereas the fast tempo music showed negative impact on fish growth when compared with control. The carcass fat content was significantly influenced by music treatment (136). Reports demonstrated that Mozart and Romanza music stimulation significantly influenced rainbow trout (*Oncorhynchus mykiss*) growth in rearing condition when compared to white noise treatment or control. An increased level of brain serotonin (5-HT) with its metabolite (5-HIAA) and decreased level of brain dopaminergic activity were observed in Mozart fish groups while Romanza and white noise fish groups showed enhanced serotonergic activity (137). Study has shown that exposure to violin music had higher growth rate in *Cyprinus carpio* than control (138). Scientists also revealed that exposure to Quran and Sufi Ney music had increased growth and feeding efficacy in *Cyprinus carpio* than Silk Road or control whereas urban noise showed negative impact on the feeding efficacy and fish growth (139). Exposure to Mozart and Romanza music has increased daily feeding consumption in *Cyprinus carpio* (140). Not only this, *Cyprinus carpio* can distinguish different kinds of music too (141). Zebrafish (*Danio rerio*) which is physiologically and genetically similar to rodents and humans enormously used as animal model in neuroscience research. Zebrafish exposed to Vivaldi's music were more active and less anxious when compared to unexposed control. Music exposed Zebra fish had reduced expression of IL-1 beta and IFN-gama pro inflammatory genes but did not affect the expression of IL-10 and IL-4 anti-inflammatory genes. Additionally, neurotrophin BNDF gene expression was elevated in the brain of zebrafish when exposed to music. Music exposure also had an anxiolytic-like behavioural pattern in *Danio rerio* (142). Study has shown that in rearing condition music had no observable effect on growth of goldfish (143).

Effect of a variety of noise exposures have also been observed in fish. Scientists have investigated that growth, behaviour and body shape was affected by repeated acoustic disturbances in larval Atlantic cod (*Gadus morhua*) (144). Report demonstrated that egg viability and larval growth was significantly reduced in two estuarine cyprinodontiform fishes - *Cyprinodon variegates* and *Fundulus similes* when exposed to high intensity noise (145). Noise treatment also had detrimental effects on three-spined sticklebacks (*Gasterosteus aculeatus*) including increased number of food handling errors and reduction of discrimination capacity between food and non-food items as a result of shifting of attention. In addition, reduced foraging efficiency and increased number of attacks for consuming the same number of prey were also noticed by noise exposure (146). When Ambon damselfish (*Pomacentrus amboinensis*) were exposed to direct as well as playback motorboat noises, an increase in metabolic rate has been investigated. Scientists also observed that fish were less responsive towards their natural predator and as a result they were captured more easily by the predator (147).

2.4 OBJECTIVE OF PRESENT STUDY

Despite plenty of detailed data on impact of audible sound on plant and animal, issues involving acoustical complexity dependent response have not been identified exactly. The obvious reason this research is extremely difficult and several empirical observations both in theory and experiment has been reported.

Accepting the reality of this type of study, we have ventured to study genre dependence of plant and animal utilizing recent concepts of tackling complex systems. In our case music as well as plants and animals belong to complex dynamical system. For music we are rich in understanding the complexity of music. On the other hand recent literature have inspired us where growth of plant and animal can be looked as manifestation of complex system and several interesting work have been reported where scaling of growth of plants and animals are not so different. A recent paper by John Damuth (148) reveals that growth scales among plants follow the same way as does among animals because growth rates of plants and animals over size ranges are common in both. This scaling approach will be applicable to find out correlations between growth rates and anatomical, ecological, physiological and environmental variables in both plants and animals.

Other authors are also interested in studying fractal properties of plants and animals. Our intention is to relate complexity of music with complexity of plant and animal growth from a new perspective choosing parameter as quantity which is emerged from the complex system. For different genres of music this parameter is Hurst exponent or DFA. For plants and animals these are germination percentage, mean germination time, stem lengthening (in case of plant) and weight gain, specific growth rate, length gain (in case of animal).

One has to note that any genre of music is a complicated mixture of frequency and amplitude and therefore in terms of frequency only or with amplitude cannot provide the exact complexity of the music rigorously. However, we have included one section in the present investigation where effects of different frequency in two different plant species have been shown for comparison seek.

Following standard protocol we have investigated a randomized control assessment on those parameters of plant and animal and tried to correlate them with complexity of music of different genre in terms of Hurst exponent or DFA. This is the objective of the present thesis using a novel technique not adopted so far.

EXPERIMENTAL FRAMEWORK

- The aim of first experiment was to find out how two different plant samples (*Pisum sativum* and *Cicerarietinum*) grow with audio signals of varying frequency but at particular amplitude. Frequency of 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz and 5000 Hz were used as audio signals here.

- The second experiment was conducted to understand the effect of music on germination of two kinds of seeds (*Pisum sativum* and *Cicer arietinum*). Indian Classical music and Natural music were used as music input for this experiment.
- The Third experiment was done to evaluate the impact of musical sound on growth of the above mentioned plant species. Four different types of musical sound namely Indian Classical music, Natural music, Contemporary music and Epic horror music were played in this experimental study as audio signals.
- The fourth and last experiment was conducted to investigate the probable effect of music exposures on physiological statuses such as growth performance and stress state as response measures in fish (*Oreochromis niloticus*). Indian Classical music and Contemporary music were considered as audio signals to stimulate fish.

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CHAPTER 3

METHODOLOGY

3.1 RANDOMIZED CONTROLLED TRIAL

3.1.1 INTRODUCTION

Randomized controlled trial (1) is one kind of quantitative scientific experiment which aims to reduce the biasness of certain sources while testing the effects of any randomly allocating subjects to groups as new treatments. Here two or more groups are treated differently and then compared in terms of a measured response. One group is the experimental group where the assessment of intervention is very important and the other is control group which has an altered condition or has no intervention (Fig. 3.1). To observe the effectiveness of the experimental intervention, both the control and experimental groups follow the conditions according to the trial designed. In randomized control trial the number of control group or treatment group may be more than one. The efficacy of the treatment is assessed by comparing the control. The trial may be blinded irrespective of selection, allocation, subject, interventions or data analysis. For reduction or elimination of experimental biasness good blinding is necessary, whereas the randomness in the allocation of subjects to different groups reduces the allocation and selection biases (2).

Randomized experiments were first conducted in agriculture by Jerzy Neyman in the early 20^{th} century (3). Later, Ronald A. Fisher also popularized for his research with randomized experiments. In the year 1948 randomized control trial was published for the first time in medicine describing the effects of streptomycin treatment in pulmonary tuberculosis (4, 5, 6, 7). Latter, randomized control trial was recognized as one of the most powerful and simplest tools in medical research. The most used common type of randomized control trial is "individually randomised, two group, parallel trial" (8).

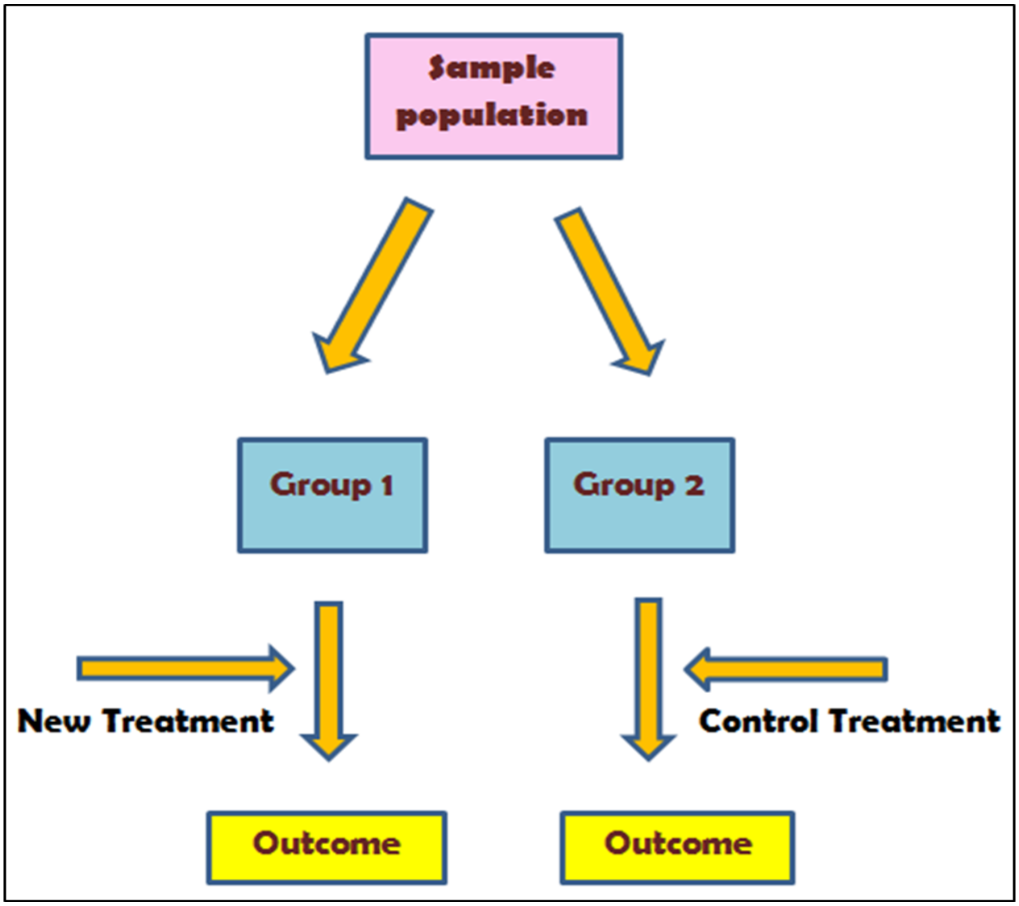

Fig.3.1 Design of a simple Randomized controlled trial

3.1.2 CLASSIFICATION

- Depending on the study designs, randomized control trial may be categorized into the following (9) -

- Parallel group-

  Here each participant is assigned to a group randomly and all participants in a group receive an intervention (or do not receive an intervention).

- Cluster

  Groups of pre-existing participants are selected randomly to receive an intervention (or not receive an intervention).

- Crossover

  Each participant of a group receives an intervention over time in a random manner (or does not receive an intervention) (10, 11).

- Factorial

  Each participant who is assigned to a randomly, receives interventions or non-interventions in a particular combination.

➢ Depending on the outcome of interest, randomized control trial are of two types-

- Explanatory

  The efficacy of a research under highly controlled conditions with highly selected participants is tested by this randomized control trial.

- Pragmatic

  The effectiveness of everyday practices occurring under flexible conditions with relatively unselected participants is tested with pragmatic randomized control trial. This test gives information related to decisions about practice (12).

➢ Depending on the methodology and reporting, categories of randomized control trial are (13) –

- Superiority trials

  In this trial one intervention is hypothetically superior to another intervention in a statistically significant way.

- Non inferiority trials

  To compare new treatment with reference treatment, this test is applicable. Non inferiority trials determine whether new treatment is not worse than the reference.

- Equivalence trials

  Trials, with two indistinguishable interventions are known as equivalence randomized control trials.

3.1.3 RANDOMIZATION

Randomization is the cornerstone of randomized control trial. For establishment of an intervention, random allocation of subjects to groups is very crucial. It minimizes the existence of confounding variables as well as the selection bias. It helps concealing the treatments from assessors or investigators. It permits the application of probability theory that the outcome differences between groups are due to chance. The following goals would be achieved from an ideal randomization procedure:

- It can maximize the statistical power during analysis of subgroups.
- Minimizes selection bias.
- It also minimizes confounding or allocation bias.

3.1.4 PROCEDURES OF RANDOMIZATION

- Simple

  Simple procedure, also known as unrestricted or complete randomization, is the commonly used intuitive procedure. This procedure has robust selection as well as accidental biases. This procedure is recommended for randomized control trials with over 200 allocated subjects (14).
- Restricted

  This type of randomization procedure is applicable in smaller randomized control trials. Two major types of this randomization are used in randomized control trials. These are –

- Blocked randomization or permuted-block randomization method

  Here two things must be specified, block size and the allocation ratio. Within each block the subjects are randomly allocated. This procedure may lead to selection bias even the block sizes are randomly varied and large. Stratification by blocks is also needed for proper data analysis from blocked randomized method.

- Adaptive biased-coin randomization method

  It is a quite uncommon method and the risk of selection bias is less than blocked randomization method. Here, the assessment probability of a group increases or decreases whether the group is underrepresented or overrepresented (15).

➢ Adaptive

The less frequently used randomization procedure is adaptive randomization. It has the following types-

- Covariate-adaptive randomization

  This method does not eliminate biasness on unknown factors. Minimization is one special type of the above method where the probability assessment of a group varies in response to minimize the covariate imbalance.

- Outcome-adaptive randomization

  It is also known as response-adaptive randomization. Here the probability assessment of a group varies with the responses of previous members in the group.

3.1.5 FACTORS AFFECTING RELIABILITY OF RANDOMIZED CONTROL TRIAL

❖ Allocation concealment

In randomized control trial allocation concealment is very important because it protects the randomization procedure. Any unclear or inadequate allocation concealment may lead to biased results. There are some standard methods of allocation concealment like sealed envelopes, opaque, sequentially numbered containers, central randomization and pharmacy controlled randomization.

- ❖ Sample size

  Sample size allocated to treatment and control groups may affect the reliability of a randomized control trial.

- ❖ Blinding

  Blinding is the procedure by which the assessors of the outcome of an experiment remain prevented from knowing the intervention. Traditionally, there are single blinded, double blinded and triple blinded randomized control trials. Randomized control trials may also be done without blinding and has been classified as open (16), open label (17) or unblended (18).

- ❖ Analysis of data

  Analysis of data by statistical methods depends on the features of the outcome data. For binary or dichotomous data, methods like logistic regression can be used. For continuous data, analysis of covariance is useful. Survival analysis is appropriate for time to event data outcome.

3.1.6 ADVANTAGES OF RANDOMIZED CONTROL TRIAL

- ♦ It is the most reliable method of scientific evidence based practices.
- ♦ Randomized control trial is very much effective in clinical research (19-27).
- ♦ Helpful in measuring the effectiveness of education, health and poverty programmes in the developing countries (28).
- ♦ Randomized control trial is also applicable in policy evaluation (29).
- ♦ Useful in criminology experiments (30).
- ♦ It is also important to account evaluation of educational interventions (31-34).
- ♦ Researchers are finding advantages using randomized control trial in transport science too (35, 36).

3.1.7 DISADVANTAGES OF RANDOMIZED CONTROL TRIAL

- Randomized control trial can be expensive, mainly for long term evaluation of any intervention (37).
- Some randomized control trial takes several years to conduct and the outcomes become less relevance at the time of publication (38).
- In cases of infrequent and rare outcomes, randomized control trials with very large sample sizes are required and therefore may be best assessed by the observational studies (39).

3.2 DETRENDED FLUCTUATION ANALYSIS OF MUSIC SIGNALS

As has already been mentioned the objective of the present research aims to find out how plant and animal growth depends on genre of music and DFA has been selected for proper assessment for characterizing music signals. In general, audio clips of 3 min each were taken and the signals were digitized at the rate of 22050 samples/sec 16 bit format. Each three minutes signal was divided into three equal segments of 60 seconds each. This was done to see the change of complexity in each time window for each clip.The DFA scaling exponent was calculated for each of the time window of 60s. DFA fora time series say {t1; t2; t3::::::tn} can be computed by following:

5. Another series T as [T(1); T(2); T(3)......T(N)] ,

   $T(k)=\sum_{i=1}^{k}(t_i - t_{mean})$. t_{mean} denotes mean of the points in the series t.
6. The series T is under interest. Series T is sliced into threads of length N. Each thread must contain this same number of element which is N. For each of the N element thread, a line is fit which signifies the trend in the thread. The fit is called Tn(k).

7. The detrending is $[T(k) - T_n\,(k)]^2$ which helps in calculation of RMS fluctuation.

F(N)= $\sqrt[2]{\frac{1}{n}\sum_{k=1}^{n}[\mathrm{T(k)} - \mathrm{T_n(k)}]^2}$ is called root mean square fluctuation.

8. F(n)$\propto$ n^{α}, a is expressed as the slope of logarithimic plot of log[F(n)] versus log(n).

Obtained α is the DFA value of a signal. It is called the DFA scaling exponent and it quantifies self-similarity and correlation properties of time series. As it suggests, a time series having has higher DFA scaling exponent is a symbolic quantification of presence of long range correlation. DFA quantifies complexity of using fractal property.

The detail experimental protocols have been discussed in respective chapters.

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CHAPTER 4

SELECTION OF DIFFERENT GENRE OF MUSIC, PLANT, AND ANIMAL SPECIES FOR THE PRESENT STUDY

4.1 INTRODUCTION

Accepting the reality of the present study, we have ventured to investigate the acoustical complexity dependent response of plant and animal to music stimuli. Considerable recent research shows response and cognition are interconnected with each other.

The planet earth is dominated by plants. Being highly sensitive to biotic and abiotic signals and acquiring resources from the environment by expending minimum energy, plants show intelligent behaviours. Proper assessment and perception of signals and making responses accordingly without proper brain and complex communications, plant intelligence now are expanding towards a new frontier of plant cognition.

Cognition in animal is not new. There are different domains of cognitive mechanisms in animal like physical, social and general. Animals have evolved under most of the same contingencies and constrains like human and scientific investigations documented many animals' ability of cognition.

Music cognition is becoming a dominant domain understanding musical knowledge, processing and assessing subsequent responses.

4.2 SELECTION OF MUSIC

As mentioned before that four different genre of music have been selected for the present study - Indian Classical music, Contemporary music, Natural music, and Epic Horror music. As we know music is composed of different periods and individual period of music is formed by different pieces. These pieces may be solely instrumental, solely vocal, combining both and so forth. The following presents a brief description about the genres of music used-

1. **Classical music:** Classical music is formal musical form of Western world and is characterized by complexity in musical form and harmonic organization. Classical music is distinct from other music traditions like folk or popular music. Classical music of Indian subcontinent is known as Indian Classical music. The North Indian Classical music and the South Indian form are two distinct traditions of Indian Classical music. The North Indian form, also known as Hindustani tradition emphasizes on raga. On the other hand the South Indian form is known as Carnatic tradition, gravitate toward short compositions. Raga and tala are two fundamental elements of Indian Classical music. The spaces between notes get priority over the notes themselves in Indian Classical music.
2. **Contemporary music:** Contemporary music is nothing but one kind of modern music comprising a broad range of compositions and which is harmonically, rhythmically and texturally belongs to present. This type of music does not follow any definite attributes. Contemporary music focuses on using modern instruments like electric guitars, synthesizers, and electronic drums. The evocative blending of combination and integration of music with technology is the essence of contemporary music.
3. **Natural music**: Music is a creation of natural environment and recent study has documented that music of many animal species have surprising structural similarities to human music. There are various sources of natural sound like bird chirping, the buzz of bee, sound of waves lapping against a coastline, flowing water sound, sound of stream, sound of rain hitting the earth, sound of leaves moving in the wind and many more. Natural music is nothing but incorporation of these natural sounds into the basic structure of contemporary music mainly instrumental to create a vivid mingling of nature and art.
4. **Horror music:** Horror music is primarily scary music dominated by shrieking sounds to build up a spooky ambience. The use of minor chords and dissonant

sounds are also found in some cases. For enhancing the level of scariness, different sound effects that imitate human fear like pulsing heartbeats, slow and heavy breathing are also played in the background.

For the present study the following musical stimuli were selected-

1) Indian Classical music -Raag Bhairavi by Kala Ramnath

2) Natural music-Sunny Mornings by Peder B. Helland

3) Contemporary music- Bombay Film Theme song by A.R. Rahman

4) Epic Horror music- Audio machine edition volume 2 Judge and Jury (Prime Cronus)

4.3 SELECTION OF PLANT SPECIES

In this dissertation two plant species have been used *Pisum sativum* (pea) and *Cicer arietinum* (chickpea or gram). Both of them belong to family-Fabaceae. To observe the possible effect of music stimuli in closely related but different plant species was the reason behind the selection of these two species.

Fabaceae family is an economically important family having world-wide distribution covering temperate, tropical forest, grass and succulent biomes (1). The family is also known as bean, pea, or legume family and includes shrubs, annual or perennial herbs and trees. Fabaceae is the third largest (land plant) family with 19,000 known species behind family Orchidaceae and Asteraceae (2, 3, 4). The family constitutes almost 7% of total flowering plant species (3). Plants under this family include mesophytes, heliophytes, and xerophytes (5, 3). Recent morphological and molecular evidences support the fact that it is a single monophyletic family (6). The family comprises a number of food and agricultural plants like pea (*Pisum sativum*), chickpea (*Cicer arietinum*), beans (*Phaseolus sp*), Soyabean (*Glycine max*), alfalfa (*Medicago sativa*), peanut (*Arachis hypogaea*) etc. Fabaceae is also important due to its medicinal uses and for the fats and oil they contain (7, 8, 9, 10). The Fabaceae family has a diverse and abundant Tertiary period fossil record. Fossils of leaves, flowers, fruits and pollens of the period have been found worldwide (11, 12, 13, 14, 15).

- ***Cicer arietinum* (CHICKPEA PLANTS)**

Binomial name: *Cicer arietinum*

Cicer arietinum or chickpea is one kind of legume,belonging to family Fabaceae and subfamily Faboideae. It has different varieties, mainly the larger kabuli and the smaller gram. Kabuli are larger, light coloured, smooth coated, whereas gram are smaller, dark coloured with a rough coat. India is the world largest producer and importer of chickpea. In 2016, 64 % of the world's chickpea was produced in India. So cultivation of chickpea is one of the major sources of income to the farmers. The high protein content of the seeds and the ability of fixing nitrogen through its roots in the soil make *Cicer arietinum* more attractive to the farmers.

Chickpea plants grow up to 50 cm in height. They have small feathery leaves arranged on either side of the shoot. The seedpod contains two to three chickpeas. Chickpeas are considered as one type of pulse. Unripe chickpeas are used as raw snack and the leaves of the legume as vegetable. The mineral content of the leaves are significantly higher than spinach and cabbage (16). Chickpea flour is also very popular in India. Chickpeas are nutrient rich food source with dietary fibre, protein, fat, vitamins and minerals (17, 18). It contains Vitamin A, B_1, B_2, B_3, B_5, B_6, B_9, Vitamin C, Vitamin E and Vitamin K. The dietary minerals it contains are iron, calcium, magnesium, phosphorus, sodium, potassium and zinc. According to WHO, the germinated and cooked chickpeas contain proteins rich in aromatic amino acids and essential amino acids like isoleucine, lysine, tryptophan (19).

Studies have shown that the consumption of chickpea may lower blood cholesterol level (20).

Pisum sativum (PEA PLANTS)

Binomial name: *Pisum sativum*

Pisum sativum is a cool-season annual plant under family Fabaceae. In the 19th century Gregor Mendel's work on *Pisum Saivum* has made the plant world famous. Throughout his experiments Mendel examined 28000 pea plants and the observations led to the foundation of modern genetics. *Pisum Saivum* plantscan be grown easily, are capable of self-pollination and pure bred strains can be developed. These characteristic features attracted Mendel for doing his experiments with *Pisum Saivum*. Like other legumes, *Pisum Saivum* also contains *Rhizobia*, one kind of symbiotic bacterium within the root nodules. These bacteria can fix atmospheric nitrogen making the plant rich in proteins. Following harvesting when the plants die in the field, the remaining nitrogen in the plants part is released back into the soil and serves as fertilizer (21, 22).

The fruit of *Pisum sativum* is known as pea pods. The fruit contains small spherical seeds commonly known as pea. Pea weighs ranges from 0.1-0.36gm. The immature green peas are very much popular as vegetables.Raw pea is nutrient rich food which contains carbohydrates, dietary fibres, proteins, vitamin A, beta-carotene, lutein zeaxanthin, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin C, vitamin E, vitamin K, calcium, iron, phosphorus, manganese, magnesium, sodium, potassium and zinc. In some parts of world pea milk are used as substitute of cow milk. Recent *in vitro* studies have shown that garden pea extracts have inhibitory effects on porcine pancreatic lipase (23).

4.4 SELECTION OF ANIMAL SPECIES

After having reviewed the pertinent findings, it turned out that information regarding the effect of music on fish is scanty. Despite having high demand worldwide, there is hardly any documentation regarding the effect of music on Nile tilapia (*Oreochromis niloticus*). That is the reason behind selection of Nile tilapia as a candidate fish for this study. Tilapia is the common name of cichlid fishes belonging to different genus. *Oreochromis niloticus* is one of the principal commercial species of tilapia.

Tilapias are freshwater fish and mainly found in ponds, streams, lakes, rivers and less likely in brackish water. They are group of cichlids originated from Africa and Middle East. Many countries consider Tilapia as invasive species for disrupting native species significantly. Now they are farmed almost all over the world as important food fish. Tilapias are easily identified by laterally compressed deep bodied fish with an interrupted lateral line which are also characteristic features of the Cichlid family of fishes. They are good feeders and with the help of both true jaws and pharyngeal jaws, can capture and process a wide variety of food items. They have protrusible mouth bordered with wide swollen lips. They have long heavily spined dorsal fin and less spiny anal fins. Tilapias are mouth brooder. They are more resistant fish than other cultured fish to different bacterial, viral and parasitic diseases. Tilapia contains good amount of protein and low in carbohydrates, saturated fat, sodium and calories. Tilapias are also source of potassium, selenium, phosphorus, niacin and vitamin $B_{12.}$ Along with these, their mild taste and low price makes them very popular across the world.

- ***Oreochromis niloticus* (Nile Tilapia)**

Binomial name: ***Oreochromis niloticus***

Nile tilapia, *Oreochromis niloticus* (L.), is an economically important species of Tilapia and an ideal candidate for aquaculture and aquaponics worldwide. The first fish species cultured was Nile tilapia. In captivity, they spawn easily, consume a wide variety of natural as well as formulated foods, grow rapidly at warm temperatures, able to resist disease, tolerate high stocking densities and poor quality of water. These attributes, along with early sexual maturity, ease of reproduction and spawning before attaining the market size; low input cost and high market demand have made them the species of choice in aquaculture industry (24). According to FAO (2017), there is an increasing trend of *Oreochromis niloticus* (L.) production in the cultivation industries globally. It is expected that the global production of *Oreochromis niloticus* (L.) will reach 128 million tons in 2030.

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CHAPTER 5

EFFECT OF FREQUENCY-SPECIFIC AUDIBLE SOUND SIGNALS ON *Pisum sativum* (PEA) AND *Cicer arietinum* (CHICKPEA/GRAM) PLANT GROWTH

5.1 INTRODUCTION

Audible sound treatment with distinct frequency and intensity has great potential to improve different stages of plant life cycle and it was already discussed in chapter 2. Sound of different frequencies within the audible range (20–20000 Hz) affect plant growth differently in different plant species. This work was done to find out the possible effects of different frequencies of audible sound stimulations on growth of *Pisum sativum* (pea) and *Cicer arietinum* (chickpea/gram) plants and also to detect the best sound frequency for pea and gram plant growth. Audible sound of 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz and 5000 Hz were used to stimulate *Pisum sativum* and *Cicer arietinum* plants for 336 hours. The growth of both types of plants was evaluated in terms of stem length.

5.2 METHODOLOGY

Experiments were conducted on *Pisum sativum* and *Cicer arietinum* seedlings in special sound chambers for audible sound treatments. The chambers were constructed in such a way that no outside sounds could enter the chamber. Each chamber was provided with identical speaker. The intensity was adjusted at 80 dB in the sound amplifier. Figure 5.1 shows the schematic diagram of single experimental growth chamber. Experiments were based on randomized control design with three replicates of 20 seedlings in each chamber. Eleven uniform chambers were used for each experiment taking ten chambers under treatments of sound frequency with 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz and 5000 Hz. One chamber was without any sound provided as untreated control. 660 fully emerged seedlings were taken in 33 separate pots taking 20 in each group and were potted at equal depth of 2/3th inch

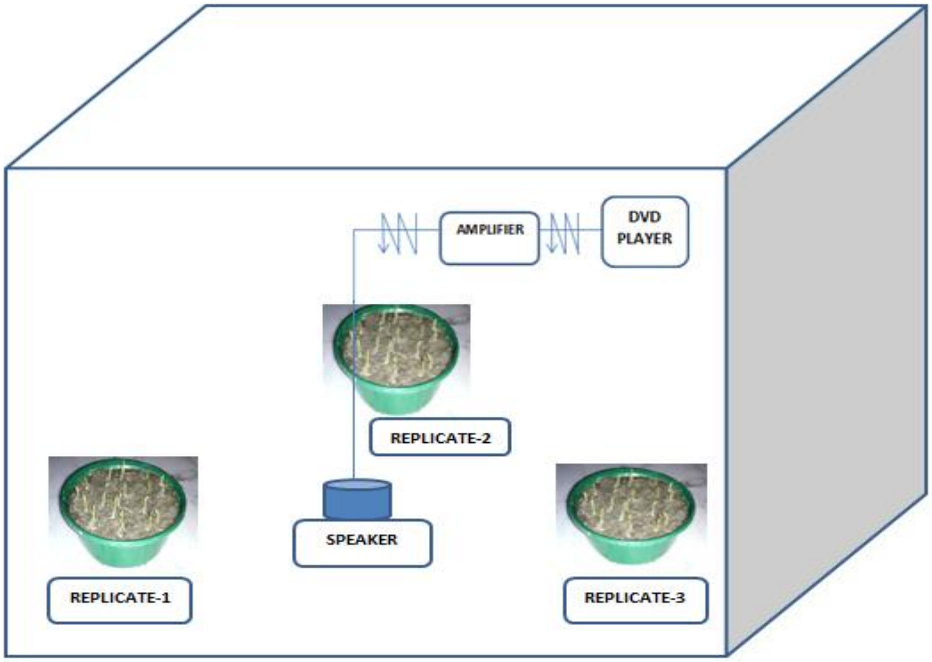


Fig.5.1: Schematic diagram of single experimental growth chamber showing triplicate pots of 20 seedlings each

A **B**

Fig.5.2: Photograph of sample A. *Pisum sativum* and B. *Cicer arietinum* seedlings sown for the experiment

inside the soil. Figure 5.2 shows the photograph of *Pisum sativum* and *Cicer arietinum* seedlings sown at starting of the experiments. All the pots were of similar size with equal amount of mud. The duration and time of sound exposure was 3 hours in the early morning between 5:30-8:30 AM and 2 hours in the evening between 4:30-6:30 PM for a period of 336 hours. Except these five hours all pots of the 11 chambers were kept in same natural environmental conditions (temperature 26 ± 2^{o}C, and humidity 66 ± 6%). The heights of plants were recorded every 48 hours with the help of a measuring tape till 336 hours and changes up to a millimeter were noted. After that no significant changes were seen in stem growth. The first experiment was conducted on *Pisum sativum* plants and second experiment on *Cicer arietinum* plants**.**

5.3 <u>RESULTS</u>

The heights of plants (stem length) were measured every 48 hours till the end of the experiment to evaluate stem length differences among treated and control plants. The measured data were used to derive differences in plant growth rate of ten different frequency stimulated plants over the untreated control plants. Graphs were also drawn from these data to make the results more perceivable and to interpret easily.

5.3.1 GROWTH ANALYSIS IN *Pisum sativum* PLANT

Figure 5.3 shows the photograph of control and ten different frequency stimulated *Pisum sativum* plants after 144 hours (Replicate-2). Table 5.1, Table 5.2, Table 5.3, Table 5.4, Table 57.5, Table 5.6, Table 5.7, Table 5.8, Table 5.9, Table 5.10 and Table 5.11 shows the detail replicate-1 data of *Pisum sativum* plant growth in terms of stem length in cm. with time in hours for control, 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz and 5000 Hz treatment respectively. Table 5.12, Table 5.13, Table 5.14, Table 5.15, Table 5.16,

Table 5.17, Table 5.18, Table 5.19, Table 5.20, Table 5.21 and Table 5.22 are the same for replicate-2 pea plants. Sequentially, Table 5.23, Table 5.24, Table 5.25, Table 5.26, Table 5.27, Table 5.28, Table 5.29, Table 5.30, Table 5.31, Table 5.32 and Table 5.33 manifests growth data of control and the above mentioned frequency stimulated replicate-3 pea plants respectively.

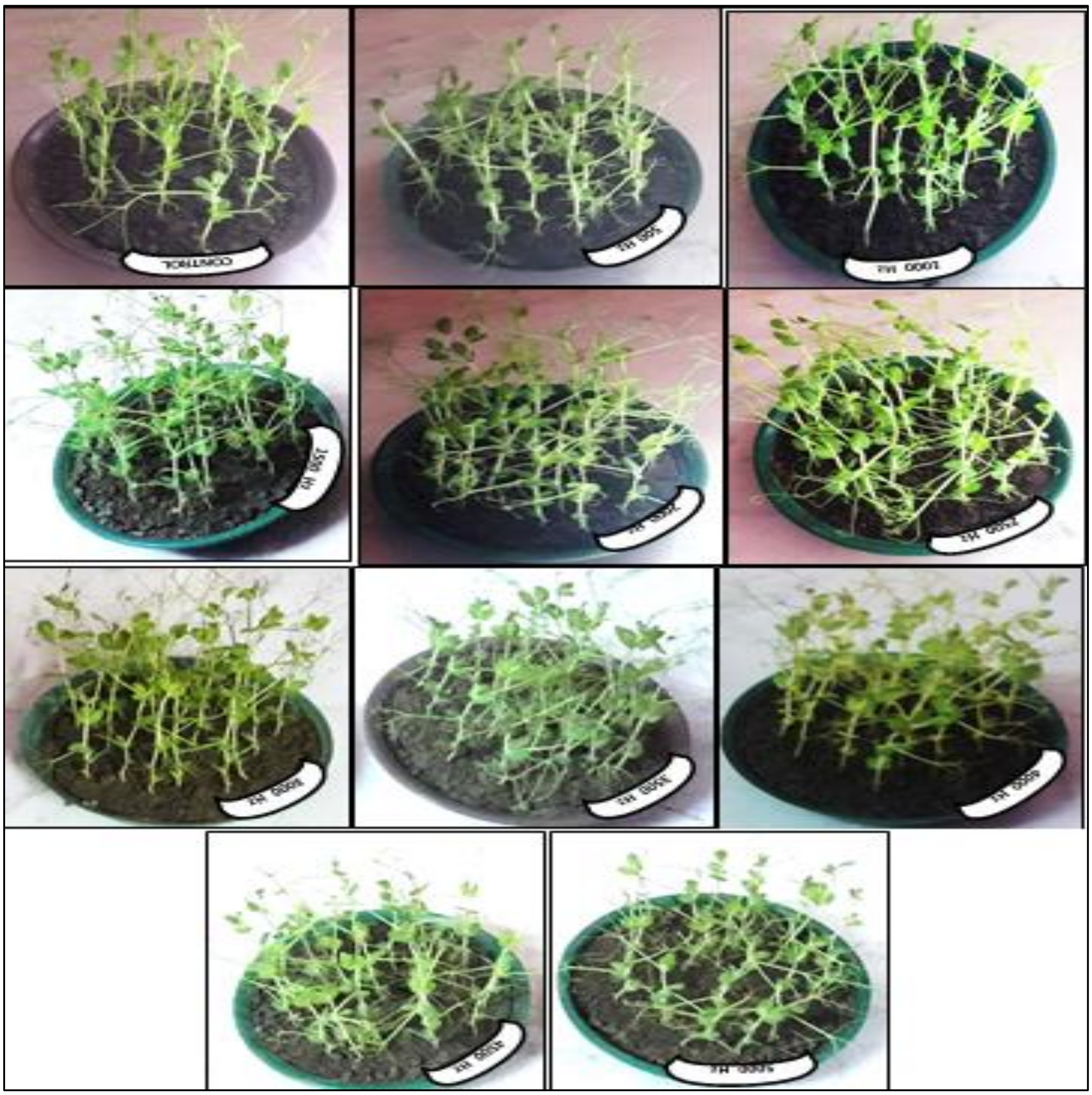


Fig.5.3: Photograph of control and ten different frequency stimulated *Pisum sativum* plants after 144 hours (Replicate-2).

Replicate-1

Table 5.1: ***Pisum sativum*** **plant growth in terms of stem length in cm. with time in hours without any sound treatment**

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	3.9	7.9	12.8	17.2	21.0	25.0
2	2.0	3.9	8.0	12.9	17.2	21.1	25.1
3	2.1	3.9	8.0	13.0	17.4	21.2	25.1
4	2.1	4.0	7.9	12.9	17.2	21.0	25.2
5	1.9	4.0	8.1	13.0	17.3	21.1	25.2
6	1.9	3.9	8.0	13.0	17.4	21.2	25.3
7	1.9	3.8	7.9	12.8	17.1	21.0	25.0
8	1.8	3.7	7.8	12.8	17.4	21.2	25.2
9	2.0	4.1	8.1	12.9	17.3	21.2	25.3
10	2.1	4.1	8.2	13.0	17.4	21.2	25.2
11	2.0	4.0	7.9	12.8	17.0	21.0	25.1
12	2.0	4.0	8.0	12.9	17.1	21.0	25.0
13	2.1	4.0	8.0	13.0	17.4	21.2	25.2
14	2.1	4.1	8.0	13.0	17.3	21.3	25.3
15	1.9	3.8	7.8	12.7	17.1	20.9	25.0
16	1.9	3.9	7.9	12.9	17.3	21.0	25.0
17	1.9	4.0	8.2	13.0	17.4	21.2	25.3
18	1.8	3.8	7.8	12.8	17.0	20.9	25.0
19	1.8	4.0	8.1	13.0	17.3	21.2	25.1
20	1.7	3.7	7.8	12.7	17.0	20.9	25.0
Sum	38.9	78.6	159.4	257.9	344.8	421.8	502.6
Average	1.945	3.93	7.97	12.895	17.24	21.09	25.13
SD	0.11	0.11	0.12	0.10	0.14	0.12	0.11

<u>Replicate-1</u>

Table 5.2: 500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.0	4.1	8.3	13.3	17.9	22.1	26.4
2	1.9	3.8	8.0	13.2	17.9	22.2	26.5
3	1.9	3.9	8.1	13.1	17.8	22.0	26.4
4	2.0	4.0	8.4	13.2	17.9	22.1	26.5
5	2.1	4.2	8.4	13.3	18.0	22.3	26.6
6	2.0	4.1	8.3	13.4	18.0	22.2	26.6
7	2.0	4.0	8.2	13.3	18.0	22.3	26.6
8	1.9	3.9	8.0	13.1	17.8	22.1	26.6
9	1.8	3.8	8.0	13.0	17.8	22.0	26.4
10	2.1	4.1	8.3	13.3	17.9	22.1	26.5
11	2.0	4.1	8.3	13.4	17.9	22.2	26.6
12	2.1	4.2	8.4	13.4	18.0	22.2	26.4
13	2.1	4.3	8.4	13.3	17.9	22.1	26.5
14	2.1	4.1	8.3	13.2	17.9	22.1	26.6
15	1.8	3.8	7.9	13	17.7	22.0	26.5
16	1.9	3.8	8.0	13.1	17.8	22.0	26.4
17	2.1	4.1	8.3	13.4	18.0	22.1	26.5
18	2.0	4.1	8.4	13.4	18.0	22.2	26.6
19	2.1	4.1	8.4	13.3	17.9	22.1	26.5
20	2.0	4.0	8.3	13.4	18.0	22.2	26.6
Sum	39.9	80.5	164.7	265.1	358.1	442.6	530.3
Average	1.995	4.025	8.235	13.255	17.905	22.13	26.515
SD	0.09	0.14	0.16	0.13	0.08	0.09	0.07

Replicate-1

Table 5.3: 1000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.5	9.1	14.2	19.1	24.0	28.9
2	2.0	4.2	8.7	14.0	19.0	24.0	29.0
3	2.1	4.2	8.8	14.0	19.1	24.1	29.1
4	2.1	4.2	8.8	14.1	19.1	24.2	29.1
5	2.1	4.3	8.9	14.0	19.0	24.1	29.2
6	2.0	4.2	8.7	14.0	19.0	24.0	29.1
7	2.2	4.3	8.9	14.2	19.2	24.2	29.0
8	2.2	4.4	9.0	14.2	19.1	24.1	29.1
9	2.2	4.5	9.1	14.2	19.3	24.2	29.1
10	2.1	4.3	9.0	14.1	19.2	24.1	29.0
11	2.1	4.3	8.9	14.0	19.0	24.0	29.0
12	2.2	4.5	9.1	14.2	19.2	24.2	29.1
13	2.2	4.4	9.0	14.2	19.3	24.3	29.2
14	2.2	4.5	9.1	14.0	19.1	24.2	29.2
15	2.1	4.3	8.9	14.0	19.1	24.1	29.1
16	2.1	4.2	8.7	14.0	19.0	24.3	29.3
17	2.1	4.3	8.9	14.2	19.2	24.2	29.3
18	2.1	4.3	8.9	14.1	19.2	24.1	29.2
19	2.1	4.2	8.8	14.1	19.1	24.0	29.0
20	2.2	4.5	9.1	14.2	19.2	24.0	28.9
Sum	42.6	86.6	178.4	282	382.5	482.4	581.9
Average	2.13	4.33	8.92	14.1	19.125	24.12	29.095
SD	0.06	0.11	0.13	0.08	0.09	0.09	0.11

Replicate-1

Table 5.4: 1500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.8	9.8	14.9	19.8	25.5	31.6
2	2.4	4.8	9.7	14.8	19.9	25.6	31.5
3	2.3	4.7	9.6	14.8	19.9	25.5	31.5
4	2.4	4.7	9.7	14.9	20	25.5	31.6
5	2.3	4.8	9.8	14.8	19.9	25.6	31.5
6	2.4	4.8	9.6	14.7	19.9	25.5	31.4
7	2.5	4.9	9.7	14.9	20.0	25.6	31.5
8	2.3	4.7	9.8	15.0	20.0	25.5	31.6
9	2.4	4.8	9.7	14.9	19.9	25.5	31.6
10	2.4	4.7	9.8	15.0	19.9	25.5	31.6
11	2.4	4.8	9.6	14.9	19.9	25.4	31.5
12	2.3	4.7	9.7	14.8	19.8	25.6	31.4
13	2.4	4.7	9.8	14.9	19.8	25.5	31.3
14	2.5	4.9	9.8	14.9	20.0	25.5	31.5
15	2.3	4.7	9.7	14.8	19.9	25.5	31.6
16	2.4	4.8	9.7	14.9	19.8	25.6	31.3
17	2.4	4.8	9.7	14.8	19.9	25.6	31.5
18	2.3	4.7	9.7	14.9	19.9	25.5	31.4
19	2.4	4.8	9.8	15.0	19.9	25.5	31.6
20	2.3	4.7	9.7	14.9	19.8	25.4	31.6
Sum	47.5	95.3	194.4	297.5	397.9	510.4	630.1
Average	2.375	4.765	9.72	14.875	19.895	25.52	31.505
SD	0.06	0.06	0.06	0.07	0.06	0.06	0.09

Replicate-1

Table 5.5: 2000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.6	5.3	10.6	16.5	22.4	28.2	34.1
2	2.5	5.2	10.5	16.5	22.3	28.0	34.0
3	2.5	5.3	10.5	16.6	22.3	28.1	34.1
4	2.4	5.1	10.4	16.6	22.4	28.1	33.9
5	2.5	5.1	10.4	16.5	22.3	27.9	33.8
6	2.5	5.2	10.6	16.5	22.4	28.1	33.9
7	2.6	5.4	10.6	16.6	22.3	27.9	34.0
8	2.5	5.2	10.5	16.6	22.2	27.8	33.9
9	2.4	5.1	10.4	16.5	22.4	28.1	33.9
10	2.4	5.0	10.3	16.4	22.3	28.0	34.0
11	2.6	5.4	10.6	16.6	22.5	28.1	34.2
12	2.6	5.3	10.6	16.5	22.4	28.1	34.0
13	2.5	5.2	10.5	16.5	22.3	28.0	33.9
14	2.5	5.1	10.4	16.5	22.3	28.1	34.0
15	2.6	5.4	10.6	16.4	22.3	28.0	34.1
16	2.4	5.1	10.4	16.5	22.4	27.9	33.9
17	2.5	5.2	10.5	16.4	22.2	27.8	33.9
18	2.4	5.1	10.4	16.3	22.3	28.0	33.8
19	2.5	5.1	10.5	16.3	22.3	28.0	33.9
20	2.5	5.2	10.5	16.5	22.3	27.9	34.0
Sum	50.0	104.0	209.8	329.8	446.6	560.1	679.3
Average	2.5	5.2	10.49	16.49	22.33	28.005	33.965
SD	0.07	0.11	0.08	0.08	0.07	0.10	0.10

<u>Replicate-1</u>

Table 5.6: 2500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 Hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.6	5.4	11.2	17.8	23.7	29.9	35.8
2	2.6	5.4	11.1	17.8	23.8	29.9	35.7
3	2.7	5.4	11.2	17.7	23.8	29.8	35.8
4	2.6	5.3	11.1	17.7	23.8	29.7	35.8
5	2.8	5.5	11.3	17.8	23.8	29.7	35.7
6	2.6	5.2	11.1	17.6	23.9	29.7	35.8
7	2.6	5.3	11.1	17.7	24.0	29.9	35.6
8	2.6	5.4	11.1	17.7	23.9	29.7	35.7
9	2.7	5.4	11.2	17.7	23.8	29.8	35.8
10	2.7	5.5	11.3	17.8	24.0	29.8	35.9
11	2.7	5.5	11.2	17.7	23.9	29.6	35.8
12	2.7	5.4	11.2	17.8	23.9	29.8	35.8
13	2.8	5.6	11.3	17.9	24.0	30.0	35.9
14	2.7	5.5	11.2	17.8	24.0	29.9	35.7
15	2.6	5.3	11.2	17.7	23.9	29.8	35.8
16	2.7	5.4	11.2	17.6	23.8	29.9	35.7
17	2.8	5.5	11.1	17.7	23.8	29.8	35.7
18	2.6	5.3	11.1	17.8	23.8	30.1	35.9
19	2.6	5.4	11.2	17.7	23.6	29.8	35.8
20	2.6	5.2	11.3	17.8	23.6	29.9	35.7
Sum	53.3	107.9	223.7	354.8	476.8	596.5	715.4
Average	2.665	5.395	11.185	17.74	23.84	29.825	35.77
SD	0.07	0.10	0.07	0.07	0.11	0.11	0.078

Replicate-1

Table 5.7: 3000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.7	5.3	10.8	16.9	23.5	28.2	34.7
2	2.6	5.3	10.9	17.0	23.5	28.3	34.7
3	2.5	5.2	10.7	17.0	23.4	28.2	34.7
4	2.5	5.3	10.8	17.1	23.5	28.2	34.6
5	2.6	5.4	10.9	17.1	23.4	28.3	34.7
6	2.6	5.3	10.9	17.0	23.4	28.4	34.8
7	2.7	5.3	10.8	17.0	23.5	28.2	34.6
8	2.7	5.4	10.8	16.9	23.4	28.3	34.8
9	2.6	5.2	10.7	16.9	23.4	28.2	34.7
10	2.6	5.3	10.7	17.0	23.5	28.2	34.6
11	2.6	5.2	10.7	17.0	23.4	28.2	34.7
12	2.7	5.4	10.9	17.1	23.4	28.3	34.7
13	2.7	5.3	10.9	17.0	23.4	28.2	34.7
14	2.6	5.3	10.8	17.0	23.5	28.3	34.8
15	2.6	5.2	10.7	16.8	23.4	28.3	34.7
16	2.6	5.2	10.8	17.0	23.3	28.2	34.6
17	2.7	5.3	10.9	17.1	23.4	28.1	34.5
18	2.6	5.4	10.9	17.0	23.4	28.2	34.6
19	2.5	5.2	10.7	16.9	23.4	28.2	34.7
20	2.5	5.3	10.8	17.0	23.5	28.2	34.7
Sum	52.2	105.8	216.1	339.8	468.6	564.7	693.6
Average	2.61	5.29	10.805	16.99	23.43	28.235	34.68
SD	0.07	0.07	0.08	0.07	0.05	0.06	0.07

<u>Replicate-1</u>

Table 5.8: 3500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	5.0	10.2	16.1	21.6	27.1	32.9
2	2.5	5.0	10.2	16.1	21.6	27.0	32.9
3	2.5	5.1	10.3	16.2	21.6	27.0	32.8
4	2.5	5.0	10.3	16.3	21.7	27.1	32.8
5	2.4	5.1	10.3	16.2	21.5	27.0	32.9
6	2.4	4.9	10.2	16.2	21.5	27.0	32.9
7	2.5	5.0	10.2	16.1	21.5	27.1	32.9
8	2.4	5.1	10.4	16.2	21.6	27.2	32.9
9	2.6	5.2	10.4	16.4	21.7	27.2	33.0
10	2.4	4.9	10.1	16.1	21.5	27.1	32.9
11	2.5	5.1	10.2	16.1	21.5	27.0	32.9
12	2.5	5.1	10.3	16.2	21.6	27.0	32.8
13	2.6	5.0	10.1	16.2	21.6	27.0	32.7
14	2.5	5.1	10.3	16.3	21.6	27.1	32.9
15	2.4	5.0	10.2	16.3	21.6	27.2	33.0
16	2.4	5.1	10.3	16.2	21.6	27.1	32.7
17	2.5	5.2	10.4	16.1	21.5	27.0	32.8
18	2.4	5.0	10.1	16.0	21.4	27.0	32.8
19	2.6	5.1	10.4	16.2	21.6	27.2	33.0
20	2.5	4.9	10.1	16.2	21.5	27.1	32.8
Sum	49.6	100.9	205.0	323.7	431.3	541.5	657.3
Average	2.48	5.045	10.25	16.185	21.565	27.075	32.865
SD	0.06	0.08	0.10	0.09	0.07	0.07	0.08

Replicate-1

Table 5.9: 4000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.1	4.4	8.7	13.9	19.0	23.9	28.7
2	2.0	4.3	8.7	14.0	18.9	24.0	28.8
3	2.0	4.2	8.6	13.9	18.9	23.8	28.6
4	2.2	4.4	8.7	13.9	18.8	23.8	28.5
5	1.9	4.0	8.5	13.9	19.0	23.9	28.7
6	2.1	4.3	8.7	14.0	18.9	23.8	28.6
7	2.2	4.5	8.8	14.0	19.0	23.9	28.7
8	2.2	4.4	8.7	13.9	18.9	23.9	28.7
9	2.1	4.4	8.8	14.0	19.1	23.9	28.8
10	2.1	4.5	8.8	13.9	18.9	23.8	28.7
11	2.0	4.2	8.6	13.9	19.0	23.9	28.8
12	2.1	4.3	8.7	14.0	18.9	23.9	28.6
13	2.2	4.4	8.7	14.0	19.0	23.9	28.8
14	2.1	4.3	8.6	13.8	18.9	23.9	28.7
15	2.2	4.4	8.7	13.9	18.8	23.8	28.6
16	2.2	4.4	8.8	14.0	19.0	23.8	28.6
17	2.1	4.1	8.5	13.8	18.9	24.0	28.7
18	1.9	4.0	8.4	13.8	18.8	23.9	28.6
19	2.1	4.1	8.6	13.9	19.0	24.0	28.8
20	2.2	4.4	8.8	14.0	18.9	24.3	28.8
Sum	42.0	86.0	173.4	278.5	378.6	478.1	573.8
Average	2.1	4.3	8.67	13.925	18.93	23.905	28.69
SD	0.09	0.14	0.11	0.06	0.07	0.11	0.08

<u>Replicate-1</u>

Table 5.10: 4500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.0	4.0	8.0	13.0	17.4	21.3	25.5
2	1.9	4.0	8.1	12.9	17.4	21.3	25.5
3	1.9	4.1	8.1	13.1	17.5	21.5	25.4
4	2.1	4.0	8.1	13.1	17.4	21.5	25.4
5	2.0	4.0	8.0	13.0	17.5	21.4	25.3
6	1.9	4.0	8.0	13.1	17.4	21.3	25.3
7	1.9	3.8	7.9	12.9	17.4	21.3	25.3
8	2.1	4.0	7.9	13.0	17.4	21.4	25.3
9	2.0	4.0	8.2	13.1	17.5	21.3	25.4
10	2.0	4.1	8.1	13.2	17.5	21.4	25.6
11	1.9	4.0	8.1	13.0	17.6	21.5	25.3
12	1.9	4.0	8.0	12.9	17.5	21.3	25.5
13	1.9	3.9	8.0	13.1	17.6	21.5	25.6
14	1.8	3.8	7.9	13.0	17.5	21.3	25.4
15	1.8	3.9	8.0	13.0	17.5	21.4	25.4
16	1.9	3.8	8.0	13.1	17.4	21.4	25.3
17	1.9	4.0	8.1	12.9	17.4	21.3	25.3
18	2.0	3.9	8.0	13.1	17.5	21.3	25.5
19	2.1	4.2	8.1	13.2	17.4	21.3	25.3
20	2.0	3.9	8.0	12.9	17.3	21.3	25.4
Sum	39.0	79.4	160.6	260.6	349.1	427.3	508.0
Average	1.95	3.97	8.03	13.03	17.455	21.365	25.4
SD	0.08	0.10	0.07	0.09	0.07	0.07	0.10

Replicate-1

Table 5.11: 5000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.7	3.6	7.0	11.5	15.8	19.5	23.9
2	1.8	3.6	7.1	11.6	15.8	19.6	23.9
3	1.9	3.8	7.2	11.6	15.8	19.6	24.0
4	2.0	3.9	7.2	11.7	15.9	19.6	23.9
5	1.9	3.8	7.1	11.5	15.8	19.5	23.8
6	1.9	3.7	7.1	11.6	15.9	19.6	23.8
7	1.8	3.7	7.0	11.6	15.9	19.7	23.9
8	1.8	3.7	7.2	11.6	15.8	19.7	24.0
9	1.8	3.6	7.0	11.5	15.7	19.7	23.9
10	1.8	3.7	7.2	11.7	15.9	19.7	24.0
11	1.9	3.6	7.0	11.5	15.6	19.5	23.9
12	1.9	3.7	7.1	11.6	15.8	19.7	23.9
13	1.8	3.6	7.0	11.5	15.8	19.6	23.9
14	2.0	3.8	7.2	11.7	16.0	19.6	24.0
15	1.7	3.7	7.1	11.7	16.0	19.5	23.8
16	1.7	3.6	7.1	11.6	15.9	19.7	24.0
17	1.8	3.8	7.2	11.5	15.7	19.6	23.9
18	1.8	3.5	7.0	11.5	15.7	19.6	23.8
19	2.0	3.8	7.2	11.6	15.9	19.6	23.9
20	1.8	3.5	6.9	11.4	15.7	19.5	23.8
Sum	36.8	73.7	141.9	231.5	316.4	392.1	478.0
Average	1.84	3.685	7.095	11.575	15.82	19.605	23.9
SD	0.09	0.10	0.09	0.08	0.10	0.07	0.07

Replicate-2

Table 5.12: ***Pisum sativum*** **plant growth in terms of stem length in cm. with time in hourswithout any sound treatment**

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	3.9	8.0	12.9	17.2	21.1	25.0
2	1.8	3.9	8.0	12.8	17.2	21.1	25.1
3	2.0	4.0	8.1	12.9	17.3	21.3	25.2
4	2.1	4.1	7.9	12.9	17.2	21.3	25.3
5	1.9	3.9	7.9	13.0	17.4	21.3	25.2
6	1.9	3.9	8.0	12.9	17.3	21.2	25.3
7	1.9	3.8	7.9	12.8	17.2	21.0	25.1
8	1.8	3.9	7.9	12.9	17.2	21.1	25.0
9	1.8	4.0	8.0	12.9	17.3	21.2	25.1
10	1.8	3.9	8.1	13.0	17.4	21.3	25.2
11	2.0	4.0	7.9	13.0	17.3	21.3	25.1
12	2.0	3.9	8.0	12.9	17.3	21.3	25.3
13	2.0	4.0	8.1	13.0	17.4	21.2	25.2
14	2.1	4.1	8.0	13.1	17.4	21.3	25.3
15	1.8	3.9	7.9	13.0	17.4	21.2	25.2
16	1.8	3.9	7.9	12.9	17.3	21.3	25.2
17	1.9	3.8	7.9	13.0	17.4	21.3	25.3
18	1.8	3.8	7.8	12.9	17.3	21.3	25.2
19	1.8	4.0	8.1	13.0	17.3	21.2	25.2
20	1.8	3.9	7.9	12.8	17.2	21.0	25.0
Sum	37.9	78.6	159.3	258.6	346	424.3	503.5
Average	1.895	3.93	7.965	12.93	17.3	21.215	25.175
SD	0.10	0.08	0.08	0.07	0.07	0.10	0.09

Replicate-2

Table 5.13: 500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	4.1	8.1	13.2	17.7	22.0	26.4
2	1.9	4.0	8.0	13.2	17.9	22.2	26.5
3	1.9	4.1	8.1	13.1	17.8	22.2	26.6
4	2.1	4.2	8.1	13.2	17.7	22.1	26.5
5	2.0	4.1	8.2	13.3	17.7	22.0	26.5
6	1.8	4.1	8.3	13.3	17.8	22.2	26.6
7	1.9	4.1	8.2	13.1	17.7	22.1	26.5
8	1.9	4.2	8.0	13.1	17.8	22.1	26.6
9	1.8	4.0	8.1	13.1	17.7	22.0	26.4
10	1.9	4.0	8.2	13.3	17.8	22.1	26.5
11	2.1	4.2	8.3	13.3	17.9	22.2	26.6
12	1.8	4.1	8.1	13.1	17.7	22.0	26.5
13	2.0	4.1	8.2	13.3	17.8	22.1	26.5
14	2.0	4.1	8.3	13.3	17.9	22.2	26.7
15	1.9	4.0	8.3	13.2	17.8	22.0	26.5
16	1.9	3.9	8.0	13.1	17.7	22.0	26.4
17	2.0	4.1	8.3	13.2	17.7	22.0	26.5
18	2.1	4.2	8.2	13.4	17.9	22.2	26.6
19	2.0	4.1	8.1	13.3	17.9	22.1	26.5
20	1.9	4.0	8.1	13.4	17.9	22.2	26.6
Sum	38.8	81.7	163.2	264.5	355.8	442.0	530.5
Average	1.94	4.085	8.16	13.225	17.79	22.1	26.525
SD	0.09	0.07	0.10	0.09	0.08	0.08	0.07

Replicate-2

Table 5.14: 1000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 Hours	336 Hours
1	2.0	4.3	8.8	14.1	19.1	24.2	29.1
2	2.0	4.2	8.6	14.0	19.2	24.2	29.2
3	2.0	4.2	8.7	14.0	19.1	24.0	29.1
4	2.2	4.5	8.9	14.2	19.3	24.2	29.2
5	2.1	4.4	8.8	14.2	19.0	24.0	29.0
6	2.0	4.3	8.8	14.1	19.1	24.1	29.1
7	2.0	4.3	8.8	14.2	19.3	24.3	29.2
8	2.0	4.3	8.7	14.0	19.2	24.3	29.1
9	2.0	4.2	8.6	14.0	19.2	24.2	29.2
10	2.1	4.3	8.8	14.2	19.2	24.2	29.2
11	2.1	4.4	8.8	14.2	19.2	24.2	29.3
12	2.0	4.3	8.8	14.1	19.2	24.3	29.3
13	2.0	4.2	8.7	14.1	19.1	24.3	29.3
14	2.0	4.2	8.6	14.0	19.0	24.2	29.2
15	2.1	4.3	8.8	14.2	19.3	24.2	29.1
16	2.1	4.4	8.8	14.1	19.1	24.0	29.1
17	2.2	4.4	8.9	14.3	19.3	24.3	29.2
18	2.1	4.3	8.8	14.1	19.1	24.1	29.2
19	2.1	4.4	8.9	14.3	19.2	24.2	29.1
20	2.0	4.4	8.9	14.2	19.2	24.3	29.0
Sum	41.1	86.3	175.5	282.6	383.4	483.8	583.2
Average	2.055	4.315	8.775	14.13	19.17	24.19	29.16
SD	0.06	0.08	0.09	0.09	0.09	0.09	0.08

Replicate-2

Table 5.15: 1500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.7	9.7	14.8	19.9	25.4	31.3
2	2.4	4.8	9.7	14.9	19.9	25.5	31.5
3	2.5	4.9	9.9	14.8	19.9	25.5	31.5
4	2.5	4.9	9.8	14.9	20.0	25.5	31.4
5	2.4	4.9	9.8	14.9	20.0	25.4	31.5
6	2.4	4.8	9.8	14.7	19.8	25.4	31.4
7	2.5	4.8	9.9	14.9	20.0	25.6	31.6
8	2.5	4.9	9.8	15.0	20.0	25.5	31.5
9	2.4	4.8	9.9	14.9	19.9	25.5	31.5
10	2.5	5.0	9.8	15.0	19.9	25.4	31.3
11	2.4	4.8	9.9	14.9	19.9	25.5	31.4
12	2.4	4.7	9.7	14.8	19.8	25.4	31.4
13	2.4	4.7	9.7	14.7	19.8	25.4	31.5
14	2.4	4.9	9.8	14.9	20.0	25.6	31.6
15	2.4	4.8	9.8	14.8	19.9	25.5	31.6
16	2.5	5.0	9.9	14.9	19.8	25.4	31.5
17	2.3	4.7	9.7	14.8	19.9	25.5	31.5
18	2.4	4.7	9.8	14.9	19.9	25.4	31.5
19	2.4	4.8	9.8	14.8	19.9	25.5	31.6
20	2.5	4.9	9.9	14.9	20.0	25.5	31.5
Sum	48.5	96.5	196.1	297.2	398.2	509.4	629.6
Average	2.425	4.825	9.805	14.86	19.91	25.47	31.48
SD	0.06	0.09	0.07	0.08	0.07	0.06	0.08

Replicate-2

Table 5.16: 2000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	5.1	10.3	16.4	22.3	28.1	34.0
2	2.5	5.2	10.4	16.4	22.4	28.1	34.0
3	2.6	5.2	10.3	16.5	22.4	28.0	34.0
4	2.6	5.3	10.4	16.4	22.3	28.0	33.9
5	2.5	5.2	10.3	16.4	22.3	28.0	34.0
6	2.6	5.2	10.5	16.5	22.5	28.1	34.2
7	2.6	5.4	10.6	16.5	22.5	28.1	34.1
8	2.5	5.2	10.5	16.6	22.5	28.2	34.1
9	2.6	5.3	10.4	16.5	22.4	28.1	33.9
10	2.4	5.1	10.3	16.5	22.5	28.1	34.0
11	2.5	5.2	10.4	16.6	22.5	28.2	34.1
12	2.6	5.3	10.5	16.5	22.5	28.1	34.0
13	2.5	5.2	10.5	16.5	22.3	27.9	33.9
14	2.6	5.4	10.6	16.6	22.4	28.0	33.9
15	2.6	5.4	10.5	16.6	22.5	28.1	34.1
16	2.6	5.1	10.4	16.5	22.4	27.9	33.9
17	2.5	5.2	10.5	16.6	22.5	28.0	34.1
18	2.4	5.1	10.3	16.4	22.5	28.1	34.0
19	2.6	5.4	10.6	16.5	22.3	28.0	34.0
20	2.6	5.3	10.5	16.5	22.3	27.9	34.0
Sum	50.9	104.8	208.8	330.0	448.3	561.0	680.2
Average	2.545	5.24	10.44	16.5	22.415	28.05	34.01
SD	0.06	0.10	0.10	0.07	0.08	0.08	0.08

Replicate-2

Table 5.17: 2500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.7	5.4	11.1	17.6	23.6	29.8	35.9
2	2.7	5.5	11.1	17.7	23.8	29.8	35.8
3	2.7	5.4	11.2	17.7	23.7	29.8	35.7
4	2.6	5.3	11.1	17.7	23.8	29.9	35.8
5	2.7	5.3	11.1	17.6	23.6	29.8	35.7
6	2.6	5.4	11.2	17.7	23.8	29.8	35.8
7	2.7	5.4	11.2	17.8	23.8	29.9	35.9
8	2.6	5.4	11.1	17.7	23.7	29.9	36.0
9	2.7	5.3	11.1	17.6	23.6	29.8	35.8
10	2.7	5.5	11.2	17.8	23.9	29.8	35.9
11	2.8	5.5	11.2	17.8	23.8	29.7	35.9
12	2.8	5.4	11.1	17.8	23.9	29.8	35.8
13	2.8	5.6	11.2	17.8	23.7	29.7	35.9
14	2.7	5.5	11.2	17.8	23.8	29.7	35.8
15	2.8	5.5	11.1	17.7	23.8	29.8	35.8
16	2.7	5.4	11.0	17.6	23.8	29.9	35.8
17	2.8	5.5	11.1	17.7	23.8	29.9	35.8
18	2.6	5.4	11.1	17.6	23.6	29.8	35.7
19	2.7	5.4	11.1	17.7	23.7	29.8	35.8
20	2.7	5.5	11.2	17.8	23.9	29.9	36.0
Sum	54.1	108.6	222.7	354.2	475.1	596.3	716.6
Average	2.705	5.43	11.135	17.71	23.755	29.815	35.83
SD	0.06	0.07	0.05	0.07	0.09	0.06	0.08

<u>Replicate-2</u>

Table 5.18: 3000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.6	5.4	10.9	16.9	23.4	28.3	34.8
2	2.7	5.5	10.9	17.0	23.4	28.4	34.7
3	2.7	5.4	10.7	16.9	23.5	28.4	34.7
4	2.7	5.3	10.7	17.1	23.5	28.5	34.8
5	2.6	5.3	10.8	17.0	23.4	28.3	34.7
6	2.7	5.5	10.9	17.0	23.5	28.4	34.8
7	2.7	5.4	10.8	17.0	23.5	28.5	34.9
8	2.5	5.3	10.8	17.0	23.4	28.3	34.8
9	2.7	5.4	10.8	16.9	23.4	28.4	34.8
10	2.7	5.3	10.7	17.0	23.4	28.3	34.7
11	2.6	5.4	10.9	17.1	23.6	28.4	34.7
12	2.7	5.4	10.9	17.1	23.6	28.5	34.9
13	2.7	5.3	10.8	17.0	23.5	28.3	34.7
14	2.6	5.4	10.8	16.9	23.5	28.3	34.7
15	2.7	5.5	10.9	17.0	23.4	28.3	34.7
16	2.7	5.4	10.8	17.0	23.5	28.3	34.6
17	2.5	5.4	10.9	17.1	23.6	28.2	34.6
18	2.6	5.4	10.9	17.0	23.5	28.2	34.6
19	2.5	5.3	10.7	17.0	23.4	28.2	34.7
20	2.7	5.3	10.8	17.0	23.5	28.2	34.7
Sum	52.9	107.6	216.4	340.0	469.5	566.7	694.6
Average	2.645	5.38	10.82	17.0	23.475	28.335	34.73
SD	0.07	0.06	0.07	0.06	0.06	0.09	0.08

<u>Replicate-2</u>

Table 5.19: 3500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.9	10.2	16.3	21.8	27.3	33.0
2	2.5	4.9	10.1	16.2	21.6	27.2	32.8
3	2.4	4.9	10.0	16.2	21.7	27.2	32.9
4	2.4	4.8	10.1	16.3	21.8	27.3	33.0
5	2.4	5.0	10.2	16.2	21.8	27.2	32.9
6	2.4	4.8	10.1	16.3	21.8	27.3	32.9
7	2.5	5.0	10.2	16.1	21.7	27.1	32.8
8	2.5	5.0	10.1	16.2	21.7	27.2	32.9
9	2.4	5.0	10.4	16.3	21.8	27.3	32.9
10	2.4	4.9	10.3	16.2	21.7	27.1	32.9
11	2.5	5.1	10.3	16.3	21.8	27.3	32.9
12	2.4	4.8	10.1	16.2	21.7	27.2	32.8
13	2.5	5.0	10.3	16.3	21.8	27.3	33.0
14	2.5	5.0	10.3	16.3	21.7	27.1	32.8
15	2.6	5.0	10.2	16.3	21.6	27.1	32.9
16	2.6	5.0	10.2	16.3	21.7	27.1	32.8
17	2.4	4.8	10.1	16.1	21.5	27.1	32.7
18	2.4	4.9	10.1	16.3	21.7	27.2	32.9
19	2.5	5.0	10.3	16.3	21.8	27.3	33.0
20	2.4	4.9	10.2	16.2	21.7	27.1	32.8
Sum	49.1	98.7	203.8	324.9	434.4	544	657.6
Average	2.455	4.935	10.19	16.245	21.72	27.2	32.88
SD	0.06	0.08	0.09	0.06	0.08	0.08	0.08

Replicate-2

Table 5.20: 4000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.3	8.6	13.9	18.9	23.9	28.8
2	2.1	4.3	8.7	13.9	18.9	23.8	28.8
3	2.1	4.4	8.7	14.0	18.9	24.0	28.9
4	2.1	4.3	8.6	13.9	19.0	24.0	28.8
5	2.0	4.2	8.5	13.8	19.0	23.9	28.9
6	2.0	4.3	8.7	14.0	18.9	23.9	28.8
7	2.1	4.4	8.8	14.0	19.0	23.9	29.0
8	2.2	4.4	8.8	14.0	19.0	24.0	29.0
9	2.1	4.3	8.6	13.9	19.0	23.9	28.8
10	2.1	4.3	8.7	13.9	18.9	23.9	28.9
11	2.0	4.2	8.5	13.8	18.9	23.9	28.8
12	2.0	4.2	8.6	13.9	19.0	23.9	28.9
13	2.1	4.3	8.8	14.0	19.0	24	28.8
14	2.0	4.3	8.6	13.8	19.0	23.9	28.8
15	2.2	4.4	8.8	14.0	19.1	24.1	29.0
16	2.2	4.4	8.8	14.0	19.0	23.8	28.9
17	2.1	4.4	8.7	13.9	18.9	24.0	29.0
18	2.0	4.3	8.6	13.9	18.9	23.9	28.8
19	2.1	4.4	8.7	13.9	19.0	24.1	28.9
20	2.1	4.3	8.6	13.9	18.9	24.0	28.8
Sum	41.8	86.4	173.4	278.4	379.2	478.8	577.4
Average	2.09	4.32	8.67	13.92	18.96	23.94	28.87
SD	0.07	0.06	0.09	0.06	0.05	0.08	0.07

Replicate-2

Table 5.21: 4500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.8	3.9	8.0	13.0	17.4	21.4	25.4
2	1.8	4.0	8.0	12.9	17.4	21.3	25.5
3	1.9	4.0	8.1	13.0	17.5	21.5	25.5
4	2.0	4.1	8.1	13.1	17.5	21.4	25.4
5	1.8	3.9	7.9	13.0	17.5	21.3	25.5
6	2.0	4.0	8.0	13.1	17.6	21.5	25.3
7	1.9	3.9	7.9	13.0	17.6	21.4	25.5
8	2.0	4.0	7.9	13.0	17.5	21.4	25.4
9	1.8	3.9	8.0	12.9	17.5	21.5	25.5
10	2.0	4.1	8.1	13.0	17.6	21.4	25.4
11	1.8	3.9	8.1	13.0	17.5	21.5	25.4
12	1.9	3.9	8.0	12.9	17.5	21.3	25.5
13	2.0	3.9	8.0	13.1	17.6	21.5	25.6
14	1.8	3.8	7.9	13.0	17.5	21.5	25.4
15	1.9	3.9	8.0	12.9	17.4	21.4	25.4
16	1.8	4.0	7.8	12.9	17.4	21.5	25.5
17	2.0	4.0	8.1	12.9	17.5	21.4	25.3
18	1.9	4.0	8.0	13.0	17.5	21.3	25.5
19	2.0	4.1	8.0	13.1	17.6	21.5	25.4
20	1.9	3.9	8.0	12.9	17.5	21.3	25.4
Sum	38.0	79.2	159.9	259.7	350.1	428.3	508.8
Average	1.9	3.96	7.995	12.985	17.505	21.415	25.44
SD	0.08	0.08	0.08	0.07	0.06	0.07	0.07

Replicate-2

Table 5.22: 5000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	3.8	7.2	11.7	15.9	19.8	24.0
2	1.8	3.7	7.1	11.6	15.9	19.9	23.9
3	2.0	3.9	7.2	11.6	16.0	19.9	24.0
4	2.0	3.9	7.3	11.7	16.0	20.0	23.9
5	1.8	3.8	7.1	11.6	15.9	19.9	23.9
6	1.8	3.7	7.1	11.6	15.9	19.8	23.8
7	1.8	3.7	7.2	11.7	15.9	19.8	23.9
8	1.9	3.9	7.3	11.7	15.9	19.9	23.9
9	1.8	3.8	7.2	11.7	16.0	20.0	23.8
10	1.9	3.7	7.2	11.7	16.0	19.9	24.0
11	2.0	3.9	7.3	11.6	15.9	20.0	23.9
12	1.9	3.8	7.1	11.6	15.9	19.9	23.9
13	1.8	3.8	7.2	11.7	16.0	19.9	24.0
14	1.9	3.9	7.3	11.7	16.1	20.0	24.0
15	1.8	3.7	7.1	11.7	16.0	20.0	23.8
16	2.0	4.0	7.4	11.8	16.1	19.9	24.0
17	1.8	3.8	7.2	11.7	16.0	19.9	23.9
18	1.9	3.8	7.1	11.6	15.9	20.0	23.8
19	1.8	3.8	7.2	11.7	15.9	19.9	24.0
20	1.9	3.9	7.2	11.6	15.9	20.0	23.9
Sum	37.5	76.3	144.0	233.3	319.1	398.4	478.3
Average	1.875	3.815	7.2	11.665	15.955	19.92	23.915
SD	0.07	0.08	0.08	0.05	0.06	0.06	0.07

Replicate-3

Table 5.23: *Pisum sativum* plant growth in terms of stem length in cm. with time in hours without any audible sound treatment

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	3.9	7.9	12.9	17.3	21.2	25.2
2	2.0	4.0	7.9	12.8	17.2	21.3	25.4
3	1.8	3.9	8.0	13.0	17.3	21.3	25.3
4	1.7	3.8	7.9	12.9	17.3	21.2	25.3
5	1.9	3.9	8.0	13.0	17.4	21.4	25.3
6	1.9	3.9	8.0	12.9	17.4	21.3	25.3
7	1.9	3.8	7.8	12.8	17.2	21.3	25.2
8	1.8	3.8	7.8	12.9	17.3	21.4	25.2
9	1.9	4.0	8.0	12.9	17.3	21.3	25.3
10	1.7	3.8	7.9	13.0	17.4	21.3	25.2
11	1.8	4.0	7.9	12.8	17.3	21.3	25.3
12	1.9	4.0	8.0	12.9	17.3	21.4	25.3
13	1.8	4.0	7.9	13.0	17.4	21.3	25.2
14	1.9	4.0	8.0	12.8	17.3	21.4	25.3
15	1.9	3.8	7.8	12.9	17.4	21.3	25.4
16	1.9	3.9	7.9	12.9	17.3	21.3	25.2
17	1.8	3.8	8.0	13.0	17.4	21.3	25.2
18	1.8	3.8	7.8	12.8	17.2	21.2	25.3
19	1.8	3.9	8.1	13.0	17.3	21.2	25.3
20	1.7	3.8	7.8	12.9	17.4	21.4	25.3
Sum	36.8	77.8	158.4	258.1	346.4	426.1	505.5
Average	1.84	3.89	7.92	12.905	17.32	21.305	25.275
SD	0.08	0.08	0.08	0.07	0.06	0.06	0.06

Replicate-3

Table 5.24: 500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment –500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	4.1	8.3	13.4	17.9	22.3	26.8
2	2.0	4.0	8.1	13.3	17.8	22.2	26.6
3	1.9	4.0	8.2	13.4	17.9	22.2	26.7
4	2.0	4.2	8.3	13.5	17.9	22.3	26.8
5	2.0	4.1	8.3	13.5	17.9	22.4	26.8
6	1.9	4.1	8.2	13.4	17.8	22.2	26.7
7	2.0	4.1	8.3	13.4	17.7	22.2	26.7
8	1.9	4.0	8.2	13.3	17.8	22.2	26.6
9	1.9	4.0	8.1	13.3	17.9	22.3	26.7
10	1.9	4.1	8.3	13.5	17.9	22.2	26.7
11	1.8	4.0	8.1	13.3	17.8	22.2	26.7
12	1.8	4.0	8.2	13.3	17.8	22.2	26.6
13	1.8	4.0	8.2	13.4	17.8	22.3	26.8
14	2.0	4.1	8.2	13.4	17.9	22.3	26.7
15	1.9	4.1	8.3	13.5	17.9	22.4	26.7
16	2.0	4.0	8.3	13.4	18.0	22.4	26.8
17	1.9	4.1	8.2	13.4	18.0	22.5	26.8
18	2.0	4.2	8.4	13.4	17.9	22.2	26.7
19	1.8	4.0	8.2	13.4	18.0	22.5	26.9
20	2.0	4.0	8.1	13.3	17.9	22.3	26.6
Sum	38.4	81.2	164.5	267.8	357.5	445.8	534.4
Average	1.92	4.06	8.225	13.39	17.875	22.29	26.72
SD	0.07	0.06	0.08	0.07	0.07	0.09	0.08

Replicate-3

Table 5.25: 1000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.1	4.3	8.8	14.2	19.2	24.1	29.4
2	2.0	4.3	8.9	14.4	19.3	24.3	29.3
3	2.2	4.4	8.8	14.1	19.2	24.3	29.2
4	2.1	4.3	8.8	14.2	19.4	24.3	29.3
5	2.0	4.3	8.7	14.2	19.3	24.4	29.2
6	2.2	4.4	8.8	14.1	19.4	24.3	29.3
7	2.0	4.3	8.7	14.1	19.2	24.4	29.4
8	2.0	4.2	8.7	14.3	19.4	24.4	29.3
9	2.0	4.3	8.8	14.2	19.3	24.2	29.4
10	2.0	4.2	8.7	14.1	19.2	24.4	29.4
11	2.1	4.3	8.7	14.2	19.4	24.3	29.2
12	2.0	4.3	8.9	14.3	19.2	24.2	29.3
13	2.1	4.4	8.8	14.2	19.3	24.3	29.1
14	2.0	4.2	8.8	14.3	19.3	24.2	29.2
15	2.1	4.4	8.9	14.2	19.3	24.4	29.3
16	2.1	4.3	8.8	14.3	19.2	24.3	29.4
17	2.0	4.3	8.8	14.2	19.1	24.3	29.3
18	2.1	4.3	8.9	14.4	19.4	24.4	29.2
19	2.0	4.3	8.8	14.1	19.2	24.3	29.4
20	2.1	4.4	9.0	14.3	19.4	24.4	29.2
Sum	41.2	86.2	176.1	284.4	385.7	486.2	585.8
Average	2.06	4.31	8.805	14.22	19.285	24.31	29.29
SD	0.06	0.06	0.08	0.09	0.09	0.08	0.08

Replicate-3

Table 5.26: 1500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.8	9.8	14.9	19.9	25.4	31.3
2	2.3	4.7	9.7	14.7	19.8	25.4	31.4
3	2.3	4.7	9.8	14.8	19.9	25.3	31.5
4	2.4	4.8	9.7	14.8	20.0	25.4	31.4
5	2.5	4.9	9.9	14.7	19.9	25.4	31.4
6	2.3	4.7	9.8	14.7	19.8	25.3	31.3
7	2.5	5.0	9.9	14.8	19.9	25.4	31.3
8	2.3	4.8	9.9	14.9	20.0	25.5	31.5
9	2.5	4.9	9.8	14.9	19.9	25.4	31.4
10	2.4	4.7	9.8	14.8	19.9	25.5	31.3
11	2.3	4.8	9.7	14.8	19.8	25.4	31.5
12	2.3	4.8	9.8	14.9	19.9	25.5	31.4
13	2.4	4.8	9.8	14.9	19.8	25.3	31.3
14	2.5	5.0	10.0	14.9	20.0	25.5	31.5
15	2.5	4.9	9.7	14.8	19.9	25.4	31.4
16	2.4	4.8	9.9	14.8	19.8	25.3	31.3
17	2.4	4.9	9.8	14.8	19.9	25.3	31.4
18	2.3	4.7	9.8	14.7	19.7	25.3	31.4
19	2.4	4.8	9.8	15.0	19.9	25.5	31.6
20	2.5	4.9	9.8	14.7	19.8	25.3	31.5
Sum	47.9	96.4	196.2	296.3	397.5	507.8	628.1
Average	2.395	4.82	9.81	14.815	19.875	25.39	31.405
SD	0.08	0.09	0.07	0.08	0.07	0.07	0.08

Replicate-3

Table 5.27: 2000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	5.1	10.2	16.3	22.3	28.0	34.0
2	2.4	5.0	10.2	16.2	22.3	28.0	34.0
3	2.5	5.0	10.1	16.2	22.2	27.8	33.9
4	2.5	5.2	10.3	16.2	22.1	27.8	33.8
5	2.5	5.2	10.2	16.1	22.2	27.9	33.8
6	2.6	5.1	10.3	16.3	22.2	27.8	33.9
7	2.5	5.0	10.1	16.2	22.1	27.7	33.8
8	2.4	5.0	10.2	16.3	22.3	27.9	33.9
9	2.5	5.1	10.2	16.2	22.1	27.7	33.8
10	2.4	5.1	10.3	16.2	22.3	28.0	34.0
11	2.5	5.2	10.4	16.3	22.1	27.7	33.8
12	2.5	5.1	10.3	16.2	22.2	27.8	33.9
13	2.4	5.1	10.3	16.3	22.2	27.8	33.8
14	2.5	5.3	10.4	16.3	22.1	27.7	33.7
15	2.5	5.2	10.4	16.3	22.3	28.0	34.0
16	2.5	5.1	10.3	16.3	22.4	27.9	33.8
17	2.4	5.1	10.2	16.3	22.2	27.8	33.9
18	2.6	5.3	10.4	16.3	22.2	27.8	33.9
19	2.5	5.2	10.4	16.4	22.3	28.0	33.9
20	2.4	5.0	10.2	16.3	22.3	27.9	34.0
Sum	49.5	102.4	205.4	325.2	444.4	557.0	677.6
Average	2.475	5.12	10.27	16.26	22.22	27.85	33.88
SD	0.06	0.09	0.09	0.06	0.08	0.10	0.08

<u>Replicate-3</u>

Table 5.28: 2500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.8	5.6	11.3	17.8	23.8	29.8	35.9
2	2.6	5.4	11.2	17.8	23.9	29.9	36.0
3	2.7	5.5	11.3	17.9	23.9	29.9	35.9
4	2.7	5.6	11.2	17.8	23.8	29.9	35.8
5	2.7	5.5	11.2	17.8	23.8	29.9	35.8
6	2.6	5.4	11.1	17.7	23.8	29.7	35.8
7	2.8	5.6	11.2	17.8	23.7	29.7	35.7
8	2.8	5.6	11.3	17.9	23.9	29.8	35.7
9	2.7	5.4	11.1	17.7	23.7	29.8	35.8
10	2.7	5.5	11.1	17.7	23.7	29.7	35.7
11	2.8	5.6	11.2	17.7	23.9	30	35.9
12	2.7	5.4	11.1	17.8	23.9	29.9	35.7
13	2.8	5.6	11.3	17.9	23.9	30	35.8
14	2.8	5.6	11.2	17.7	23.7	29.7	35.7
15	2.7	5.5	11.2	17.7	23.8	29.7	35.8
16	2.7	5.4	11.1	17.7	23.8	29.9	35.9
17	2.8	5.5	11.1	17.7	23.7	29.8	35.7
18	2.8	5.6	11.2	17.8	23.8	29.8	35.9
19	2.7	5.4	11.1	17.7	23.9	29.8	35.8
20	2.7	5.5	11.2	17.8	23.7	29.8	35.9
Sum	54.6	110.2	223.7	355.4	476.1	596.5	716.2
Average	2.73	5.51	11.185	17.77	23.805	29.825	35.81
SD	0.06	0.08	0.07	0.07	0.08	0.09	0.08

Replicate-3

Table 5.29: 3000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.6	5.4	11.0	16.9	23.5	28.3	34.8
2	2.6	5.5	10.9	16.8	23.3	28.3	34.7
3	2.7	5.5	10.9	16.9	23.4	28.3	34.8
4	2.6	5.4	10.8	16.8	23.3	28.2	34.6
5	2.6	5.3	10.8	16.9	23.4	28.2	34.7
6	2.5	5.3	10.8	17.0	23.5	28.3	34.8
7	2.6	5.3	10.9	16.9	23.4	28.2	34.6
8	2.7	5.5	10.8	16.8	23.3	28.2	34.8
9	2.6	5.4	10.9	17.0	23.4	28.2	34.8
10	2.7	5.5	11.0	16.9	23.4	28.2	34.7
11	2.6	5.3	10.8	16.9	23.4	28.3	34.8
12	2.7	5.4	10.9	16.8	23.3	28.1	34.7
13	2.7	5.4	10.8	16.9	23.4	28.3	34.8
14	2.6	5.4	10.8	16.9	23.5	28.2	34.8
15	2.5	5.3	10.8	17.0	23.5	28.2	34.7
16	2.6	5.2	10.7	16.9	23.3	28.1	34.7
17	2.5	5.3	10.8	17.0	23.5	28.3	34.8
18	2.6	5.4	10.9	17.0	23.4	28.2	34.7
19	2.7	5.5	11.0	16.9	23.4	28.3	34.8
20	2.7	5.5	10.9	17.0	23.5	28.3	34.7
Sum	52.4	107.8	217.2	338.2	468.1	564.7	694.8
Average	2.62	5.39	10.86	16.91	23.405	28.235	34.74
SD	0.06	0.08	0.08	0.07	0.07	0.06	0.06

<u>Replicate-3</u>

Table 5.30: 3500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.9	10.2	16.3	21.9	27.5	33.0
2	2.4	4.9	10.1	16.2	21.8	27.4	32.9
3	2.5	4.9	10.1	16.2	21.7	27.4	32.9
4	2.5	5.0	10.2	16.3	21.8	27.4	33.0
5	2.3	4.8	10.0	16.3	21.9	27.5	32.9
6	2.4	4.8	10.1	16.3	21.9	27.6	33.0
7	2.5	5.0	10.3	16.4	22.0	27.6	33.1
8	2.5	5.0	10.2	16.3	21.8	27.4	33.0
9	2.4	4.9	10.2	16.4	21.9	27.5	33.0
10	2.4	4.9	10.1	16.2	21.9	27.5	32.9
11	2.5	4.9	10.1	16.3	21.8	27.5	33.0
12	2.4	4.8	10.1	16.2	21.7	27.3	32.9
13	2.4	4.9	10.0	16.2	21.9	27.5	32.9
14	2.3	4.8	10.1	16.3	22.0	27.6	33.1
15	2.4	4.8	10.0	16.3	22.0	27.7	33.1
16	2.3	4.9	10.1	16.2	21.8	27.5	32.9
17	2.4	5.0	10.2	16.3	21.8	27.4	32.9
18	2.5	5.0	10.3	16.4	22.0	27.6	33.0
19	2.3	4.8	10.1	16.3	21.9	27.6	33.2
20	2.3	4.8	10.0	16.2	21.9	27.5	33.0
Sum	48.1	97.8	202.5	325.6	437.4	550.0	659.7
Average	2.405	4.89	10.125	16.28	21.87	27.5	32.985
SD	0.07	0.07	0.08	0.06	0.09	0.09	0.08

<u>Replicate-3</u>

Table 5.31: 4000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.5	8.9	14.3	19.2	24.1	28.9
2	2.2	4.4	8.8	14.2	19.2	24.2	29.1
3	2.1	4.3	8.6	14.0	19.0	24.0	29.0
4	2.2	4.5	8.9	14.2	19.3	24.3	29.0
5	2.0	4.2	8.6	14.0	19.1	24.2	28.9
6	2.2	4.4	8.7	14.0	19.0	24.1	28.8
7	2.3	4.5	8.8	14.2	19.1	24.0	29.0
8	2.3	4.4	8.8	14.2	19.1	24.1	29.0
9	2.1	4.4	8.8	14.1	19.0	24.0	29.0
10	2.2	4.4	8.7	14.1	19.1	24.0	29.0
11	2.2	4.3	8.7	14.0	19.1	24.0	28.8
12	2.2	4.5	8.9	14.3	19.2	24.1	28.8
13	2.2	4.4	8.8	14.2	19.3	24.3	28.9
14	2.1	4.3	8.7	14.1	19.0	24.1	28.9
15	2.1	4.4	8.8	14.1	19.0	24.1	28.8
16	2.0	4.3	8.7	14.2	19.1	24.0	28.9
17	2.0	4.3	8.6	14.0	19.1	24.2	29.0
18	2.2	4.4	8.8	14.1	19.1	24.1	28.9
19	2.1	4.3	8.6	14.1	19.2	24.1	28.8
20	2.1	4.4	8.7	14.1	19.0	24.0	28.9
Sum	43.0	87.6	174.9	282.5	382.2	482	578.4
Average	2.15	4.38	8.745	14.125	19.11	24.1	28.92
SD	0.08	0.08	0.09	0.09	0.09	0.09	0.08

<u>Replicate-3</u>

Table 5.32: 4500 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.8	3.9	7.9	13.0	17.5	21.4	25.6
2	1.7	3.9	8.0	13.1	17.5	21.4	25.5
3	1.9	4.1	8.1	13.1	17.6	21.5	25.5
4	2.0	4.2	8.1	13.0	17.6	21.6	25.6
5	1.9	4.0	8.0	13.0	17.5	21.5	25.4
6	1.9	4.0	8.0	13.1	17.5	21.5	25.5
7	1.8	3.9	8.0	12.9	17.4	21.3	25.4
8	2.0	4.0	7.9	13.0	17.5	21.6	25.6
9	1.9	4.0	8.1	13.1	17.5	21.6	25.5
10	1.8	3.9	8.1	13.1	17.6	21.5	25.4
11	1.8	3.8	8.0	13.1	17.6	21.5	25.5
12	1.9	3.9	8.0	12.9	17.4	21.6	25.5
13	1.9	3.9	8.1	13.1	17.6	21.5	25.5
14	1.8	3.8	7.9	13.0	17.5	21.5	25.4
15	1.8	3.8	8.0	13.0	17.4	21.5	25.5
16	1.7	3.8	8.0	13.1	17.5	21.4	25.5
17	1.9	4.0	8.1	13.0	17.5	21.6	25.5
18	1.8	4.0	8.1	13.1	17.4	21.6	25.6
19	2.0	4.2	8.1	13.2	17.6	21.5	25.5
20	1.8	3.9	8.0	12.9	17.5	21.6	25.5
Sum	37.1	79.0	160.5	260.8	350.2	430.2	510.0
Average	1.855	3.95	8.025	13.04	17.51	21.51	25.5
SD	0.08	0.11	0.06	0.08	0.07	0.08	0.06

Replicate-3

Table 5.33: 5000 Hz sound treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Treatment – 5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.8	3.7	7.0	11.6	16.0	19.9	23.9
2	1.8	3.6	7.0	11.5	15.9	19.9	23.9
3	1.9	3.7	7.1	11.6	15.9	20.0	24.1
4	1.8	3.9	7.2	11.6	16.0	19.9	24.1
5	1.8	3.8	7.3	11.7	16.1	20.0	23.9
6	1.8	3.8	7.2	11.7	15.9	20.1	24.1
7	1.8	3.9	7.2	11.6	15.9	20.1	23.9
8	1.9	3.9	7.3	11.7	16.0	20.0	24.0
9	1.8	3.7	7.0	11.5	15.9	19.9	23.9
10	1.8	3.7	7.1	11.7	16.0	19.9	24.0
11	1.8	3.8	7.2	11.6	15.9	19.9	23.9
12	1.9	3.8	7.1	11.6	15.9	20.0	24.1
13	1.8	3.8	7.2	11.7	16.0	19.9	23.9
14	1.8	3.7	7.1	11.6	16.0	20.0	24.0
15	1.9	3.8	7.1	11.5	15.8	19.9	24.1
16	1.8	3.8	7.2	11.6	15.9	19.9	24.1
17	1.9	3.9	7.2	11.7	16.0	20.0	23.9
18	1.7	3.8	7.3	11.7	16.0	19.9	23.9
19	1.8	3.9	7.3	11.7	16.1	20.1	24.0
20	1.8	3.7	7.2	11.6	16.0	19.9	24.0
Sum	36.4	75.7	143.3	232.5	319.2	399.2	479.7
Average	1.82	3.785	7.165	11.625	15.96	19.96	23.985
SD	0.05	0.08	0.09	0.06	0.07	0.07	0.08

Table 5.34 represents the control and ten distinct frequency stimulated plant growth in *Pisum sativum* measured after 48, 96, 144, 192, 240, 288, and 336 hours averaged over all the replicates. The table reveals that throughout the elapsed time

Table 5.34: Control and ten different audible frequency stimulated *Pisum sativum* plant growth averaged over of all the replicates

	48 hours	**96 hours**	**144 hours**	**192 hours**	**240 hours**	**288 hours**	**336 hours**
Control	1.89±0.11	3.91±0.10	7.95±0.10	12.91±0.09	17.28±0.11	21.20±0.13	25.19±0.11
500 Hz	1.95±0.09	4.06±0.11	8.21±0.13	13.29±0.13	17.86±0.10	22.17±0.12	26.59±0.12
1000 Hz	2.08±0.07	4.32±0.09	8.83±0.12	14.15±0.11	19.19±0.11	24.21±0.12	29.18±0.13
1500 Hz	2.4±0.07	4.8±0.09	9.8±0.08	14.9±0.09	19.9±0.07	25.5±0.09	31.5±0.10
2000 Hz	2.51±0.07	5.19±0.12	10.40±0.14	16.42±0.14	22.32±0.12	27.97±0.13	33.95±0.11
2500 Hz	2.7±0.07	5.44±0.10	11.16±0.07	17.74±0.08	23.8±0.11	29.82±0.09	35.80±0.09
3000 Hz	2.63±0.07	5.35±0.09	10.83±0.08	16.97±0.08	23.44±0.07	28.27±0.09	34.72±0.08
3500 Hz	2.45±0.08	4.96±0.11	10.19±0.11	16.24±0.09	21.72±0.15	27.26±0.20	32.91±0.10
4000 Hz	2.11±0.09	4.33±0.11	8.70±0.11	13.99±0.12	19.0±0.11	23.98±0.13	28.83±0.13
4500 Hz	1.90±0.09	3.96±0.10	8.02±0.08	13.02±0.09	17.49±0.08	21.43±0.10	25.45±0.09
5000 Hz	1.85±0.08	3.76±0.11	7.15±0.10	11.62±0.08	15.91±0.11	19.83±0.18	23.93±0.09

all frequency treated plants expressed better growth than the untreated control plants except 5000 Hz stimulation. This particular group of plants exhibited decreased plant growth than the control throughout the experimental time period. Regarding others, at the end of the experiment 2500 Hz frequency exposed plants exhibited maximum growth than control plants followed by 3000 Hz, 2000 Hz, 3500 Hz, 1500 Hz, 1000 Hz, 500 Hz, 4000 Hz, and 4500 Hz stimulated plants. Figure 5.4 is the graphical representation of table 5.34. To make the results more discernible Figure 5.5 has drawn from the above table which shows the average plant growth differences (in percentage) of different frequency treated *Pisum sativum*plants relative to the untreated control plants after 48, 96, 144, 192, 240, 288, and 336 hours. At the end of the experiment, 5.5%, 15.8%, 25.04%, 34.7%, 42.1%, 37.8%, 30.6%, 14.4%, 1.0 % higher and 5 % lower average growth relative to the untreated control plants were noted at 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz, and 5000 Hz frequency treatment respectively.

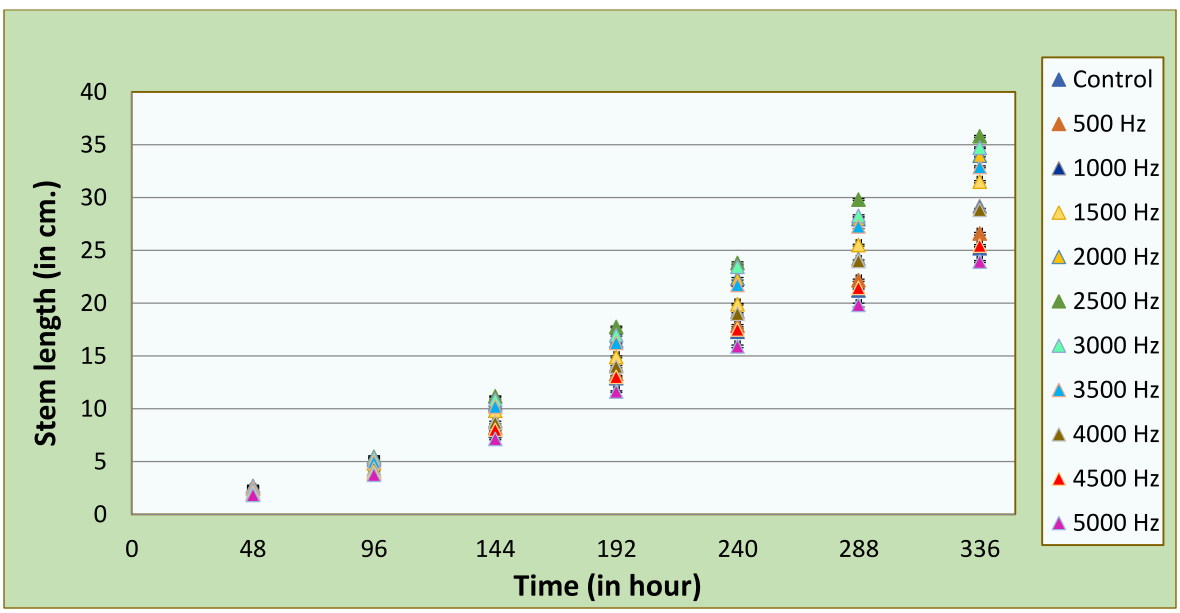


Fig.5.4: Graph showing average stem length of control and ten different audible frequency treated pea plants with time (Vertical bars represent mean ±SD)

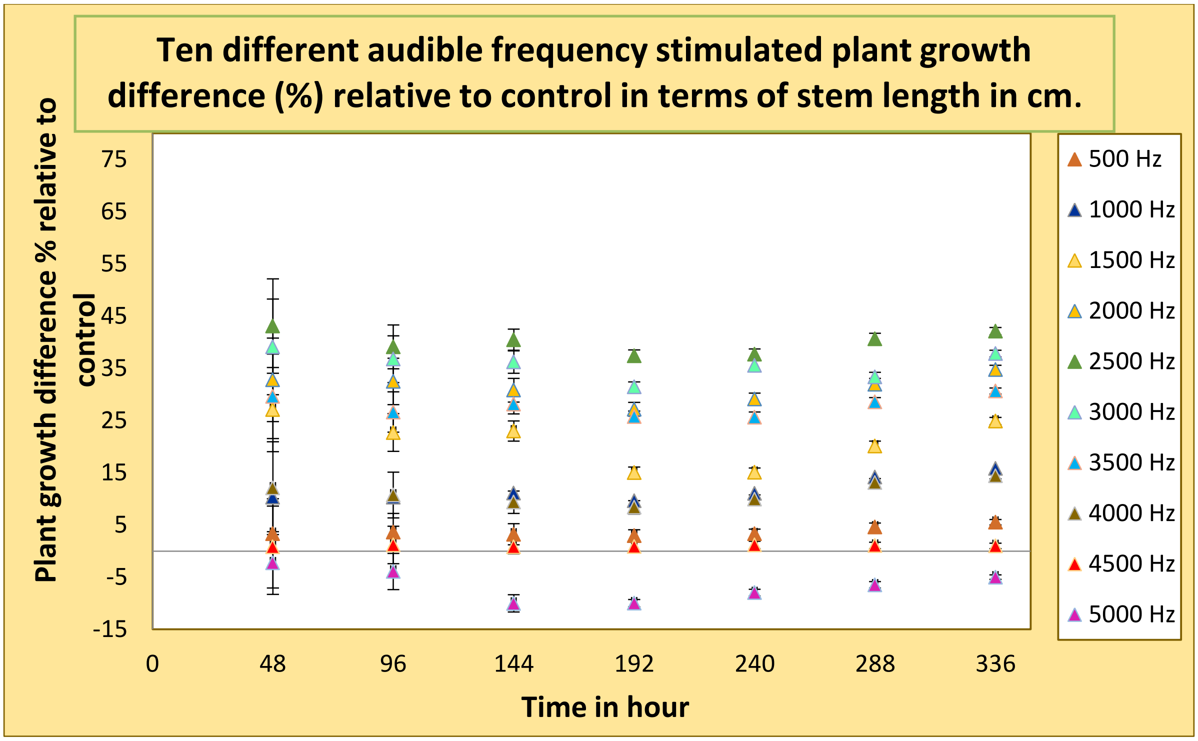


Fig.5.5: Graph showing comparative plant growth % of ten different audible frequency treated pea plants with respect to control averaged over all the replicates (Vertical bars represent mean ±SD)

5.3.2 GROWTH ANALYSIS IN *Cicer arietinum* PLANT

Figure 5.6 shows the photograph of ten different frequency stimulated and control *Cicer arietinum* plants after 144 hours (Replicate-2). The replicate-1 control, 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz and 5000 Hz frequency stimulated *Cicer arietinum* plant growth data in terms of stem length in cm. with time in hours have shown in Table 5.35, Table 5.36, Table 5.37, Table 5.38, Table 5.39, Table 5.40, Table 5.41, Table 5.42, Table 5.43, Table 5.44 and Table 5.45 respectively. Table 5.46, Table 5.47, Table 5.48, Table 5.49, Table 5.50, Table 5.51, Table 5.52, Table 5.53, Table 5.54, Table 5.55 and Table 5.56 manifests the growth data of the control and above mentioned frequency treated plants for replicate-2 gram plants. Sequentially, Table 5.57, Table 5.58,

Table 5.59, Table 5.60, Table 5.61, Table 5.62, Table 5.63, Table 5.64, Table 5.65, Table 5.66 and Table 5.67 exhibits the detail growth data of control and 10 different audible frequency treated replicate-3 gram plants.

Fig.5.6: Photograph of control and ten different frequency stimulated *Cicer arietinum* plants after 144 hours (Replicate-2).

<u>Replicate-1</u>

Table 5.35: *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours without any sound treatment

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.1	7.9	12.8	16.9	21.1	25.2
2	2.2	4.2	7.9	12.8	16.9	21.1	25.2
3	2.3	4.3	8.1	12.9	16.9	21.2	25.2
4	2.1	4.1	7.9	12.9	17.0	21.2	25.3
5	2.3	4.2	8.1	13.0	17.0	21.2	25.3
6	2.2	4.1	7.9	12.8	16.8	21.0	25.1
7	2.3	4.2	8.0	12.9	16.9	21.1	25.2
8	2.2	4.2	8.1	12.9	17.0	21.2	25.3
9	2.3	4.2	8.1	13.0	17.0	21.2	25.3
10	2.2	4.1	7.9	12.8	16.8	21.0	25.1
11	2.1	4.1	8.0	12.9	16.9	21.1	25.3
12	2.2	4.1	7.9	12.8	16.8	21.0	25.2
13	2.2	4.1	7.9	12.8	16.9	21.1	25.3
14	2.3	4.1	8.0	12.9	17.0	21.2	25.3
15	2.3	4.2	8.1	12.9	16.9	21.1	25.2
16	2.2	4.2	8.1	13.0	17.0	21.2	25.3
17	2.3	4.2	8.1	13.0	17.0	21.2	25.3
18	2.1	4.1	7.9	12.8	16.8	21.0	25.1
19	2.2	4.2	8.0	12.9	16.9	21.1	25.2
20	2.1	4.1	7.9	12.8	16.9	21.1	25.3
Sum	44.3	83.1	159.8	257.6	338.3	422.4	504.7
Average	2.215	4.155	7.99	12.88	16.915	21.12	25.235
SD	0.07	0.05	0.08	0.07	0.07	0.07	0.07

Replicate-1

Table 5.36: 500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.3	8.2	13.1	17.1	21.3	25.5
2	2.3	4.4	8.4	13.2	17.2	21.3	25.5
3	2.2	4.3	8.3	13.2	17.1	21.3	25.5
4	2.2	4.3	8.2	13.2	17.1	21.3	25.6
5	2.3	4.3	8.2	13.1	17.1	21.3	25.6
6	2.3	4.3	8.2	13.2	17.2	21.4	25.6
7	2.3	4.3	8.3	13.2	17.2	21.3	25.5
8	2.3	4.4	8.3	13.2	17.1	21.2	25.5
9	2.2	4.2	8.2	13.1	17.1	21.3	25.5
10	2.3	4.3	8.2	13.2	17.1	21.3	25.6
11	2.2	4.3	8.3	13.2	17.2	21.4	25.6
12	2.3	4.4	8.4	13.3	17.2	21.3	25.5
13	2.2	4.2	8.3	13.3	17.2	21.3	25.6
14	2.3	4.3	8.2	13.2	17.1	21.2	25.4
15	2.3	4.4	8.3	13.2	17.1	21.3	25.5
16	2.3	4.4	8.3	13.2	17.1	21.3	25.5
17	2.2	4.2	8.2	13.2	17.2	21.4	25.6
18	2.3	4.4	8.3	13.1	17.1	21.3	25.5
19	2.3	4.4	8.4	13.2	17.1	21.3	25.6
20	2.2	4.2	8.2	13.1	17.1	21.3	25.5
Sum	45.3	86.3	165.4	263.7	342.7	426.1	510.7
Average	2.265	4.315	8.27	13.185	17.135	21.305	25.535
SD	0.04	0.07	0.07	0.05	0.04	0.04	0.05

<u>Replicate-1</u>

Table 5.37: 1000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.8	9.5	14.7	19.0	23.5	27.9
2	2.4	4.7	9.5	14.8	19.1	23.6	28.0
3	2.5	4.8	9.6	14.8	19.0	23.6	27.9
4	2.4	4.8	9.6	14.8	19.0	23.5	27.9
5	2.5	4.9	9.6	14.8	19.1	23.6	27.9
6	2.4	4.8	9.6	14.8	19.0	23.5	27.9
7	2.4	4.8	9.5	14.7	19.0	23.5	27.9
8	2.5	4.9	9.6	14.8	19.0	23.6	28.0
9	2.4	4.7	9.5	14.8	19.1	23.6	28.0
10	2.5	4.9	9.6	14.8	19.1	23.5	27.8
11	2.4	4.8	9.6	14.8	19.0	23.6	27.9
12	2.4	4.7	9.5	14.7	19.0	23.5	27.8
13	2.5	4.8	9.5	14.7	19.0	23.5	27.8
14	2.4	4.7	9.5	14.7	19.0	23.5	27.9
15	2.5	4.8	9.6	14.8	19.0	23.6	28.0
16	2.4	4.7	9.5	14.8	19.1	23.6	27.9
17	2.4	4.8	9.6	14.8	19.0	23.5	27.9
18	2.4	4.8	9.5	14.7	19.1	23.6	28.0
19	2.5	4.9	9.6	14.9	19.1	23.6	28.0
20	2.4	4.7	9.5	14.7	19.0	23.5	27.9
Sum	48.7	95.8	191.0	295.4	380.7	471	558.3
Average	2.435	4.79	9.55	14.77	19.035	23.55	27.915
SD	0.04	0.07	0.05	0.05	0.04	0.05	0.06

<u>Replicate-1</u>

Table 5.38: 1500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.7	5.4	10.7	15.8	20.5	25.0	29.5
2	2.7	5.5	10.7	15.7	20.4	25.0	29.6
3	2.8	5.5	10.7	15.8	20.5	25.0	29.5
4	2.8	5.6	10.8	15.8	20.5	25.1	29.6
5	2.8	5.5	10.7	15.8	20.4	25.0	29.5
6	2.7	5.5	10.7	15.7	20.4	25.0	29.5
7	2.7	5.4	10.6	15.7	20.4	24.9	29.5
8	2.7	5.4	10.6	15.7	20.5	25.0	29.5
9	2.8	5.6	10.8	15.8	20.5	25.1	29.5
10	2.8	5.5	10.8	15.8	20.4	24.9	29.4
11	2.7	5.4	10.6	15.7	20.4	24.9	29.4
12	2.7	5.5	10.8	15.8	20.5	25.0	29.4
13	2.7	5.4	10.7	15.7	20.4	24.9	29.4
14	2.8	5.6	10.8	15.7	20.4	24.9	29.5
15	2.8	5.6	10.8	15.8	20.5	24.9	29.4
16	2.8	5.6	10.8	15.8	20.4	24.9	29.4
17	2.7	5.5	10.7	15.8	20.5	25.0	29.4
18	2.7	5.5	10.7	15.7	20.4	25.0	29.5
19	2.8	5.6	10.8	15.8	20.5	25.0	29.5
20	2.7	5.5	10.7	15.8	20.4	24.9	29.4
Sum	54.9	110.1	214.5	315.2	408.9	499.4	589.4
Average	2.745	5.505	10.725	15.76	20.445	24.97	29.47
SD	0.04	0.07	0.06	0.04	0.04	0.06	0.06

Replicate-1

Table 5.39: 2000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.0	6.1	12.2	17.5	22.3	27.2	32.0
2	3.1	6.1	12.2	17.5	22.3	27.2	32.0
3	3.1	6.1	12.1	17.4	22.1	27.0	31.9
4	3.0	6.0	12.0	17.4	22.2	27.1	31.9
5	3.0	6.1	12.1	17.5	22.2	27.1	32.0
6	3.0	6.0	12.0	17.4	22.1	27.0	31.9
7	3.1	6.1	12.2	17.5	22.3	27.1	31.9
8	3.0	6.0	12.0	17.4	22.2	27.1	32.0
9	3.0	6.0	12.1	17.5	22.3	27.2	32.0
10	3.0	6.1	12.2	17.5	22.3	27.2	32.0
11	3.0	6.0	12.0	17.4	22.2	27.0	31.9
12	3.1	6.1	12.2	17.4	22.2	27.1	31.9
13	3.1	6.1	12.2	17.5	22.2	27.1	31.9
14	3.1	6.1	12.1	17.4	22.2	27.0	31.9
15	3.0	6.0	12.0	17.4	22.1	27.0	31.9
16	3.0	6.0	12.1	17.4	22.1	27.0	31.8
17	3.0	6.1	12.2	17.5	22.3	27.1	31.9
18	3.1	6.1	12.1	17.5	22.2	27.1	31.9
19	3.0	6.0	12.1	17.4	22.1	27.0	32.0
20	3.1	6.1	12.1	17.4	22.1	27.0	31.9
Sum	60.8	121.2	242.2	348.9	444.0	541.6	638.6
Average	3.04	6.06	12.11	17.445	22.2	27.08	31.93
SD	0.04	0.04	0.07	0.04	0.07	0.07	0.05

<u>Replicate-1</u>

Table 5.40: 2500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.3	6.8	13.7	19.4	24.4	29.3	34.4
2	3.3	6.8	13.6	19.4	24.5	29.4	34.4
3	3.4	6.8	13.7	19.5	24.5	29.5	34.4
4	3.3	6.7	13.6	19.4	24.5	29.5	34.5
5	3.3	6.7	13.6	19.3	24.4	29.4	34.5
6	3.4	6.8	13.7	19.5	24.5	29.4	34.4
7	3.4	6.8	13.6	19.3	24.3	29.4	34.3
8	3.4	6.8	13.6	19.4	24.4	29.3	34.3
9	3.3	6.8	13.7	19.5	24.4	29.4	34.4
10	3.3	6.8	13.7	19.4	24.4	29.4	34.4
11	3.4	6.8	13.6	19.3	24.3	29.3	34.3
12	3.3	6.8	13.7	19.4	24.4	29.4	34.4
13	3.3	6.7	13.6	19.4	24.4	29.5	34.5
14	3.3	6.7	13.5	19.3	24.4	29.5	34.4
15	3.3	6.7	13.6	19.3	24.3	29.3	34.4
16	3.4	6.8	13.7	19.5	24.4	29.4	34.5
17	3.3	6.8	13.6	19.4	24.4	29.3	34.4
18	3.3	6.8	13.6	19.3	24.3	29.3	34.3
19	3.3	6.7	13.6	19.4	24.3	29.4	34.4
20	3.4	6.8	13.7	19.5	24.4	29.4	34.3
Sum	66.7	135.4	272.7	387.9	487.9	587.8	687.9
Average	3.335	6.77	13.635	19.395	24.395	29.39	34.395
SD	0.04	0.04	0.05	0.07	0.06	0.07	0.06

Replicate-1

Table 5.41: 3000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.1	6.3	12.5	17.8	22.7	27.8	32.8
2	3.1	6.3	12.5	17.9	22.8	27.9	32.8
3	3.2	6.4	12.5	17.8	22.8	27.8	32.9
4	3.1	6.4	12.6	17.9	22.9	27.9	32.9
5	3.2	6.4	12.6	17.9	22.8	27.8	32.9
6	3.1	6.3	12.5	17.8	22.7	27.8	32.8
7	3.1	6.3	12.4	17.8	22.8	27.9	32.9
8	3.1	6.3	12.5	17.9	22.8	27.7	32.8
9	3.1	6.4	12.6	17.9	22.8	27.8	32.9
10	3.1	6.3	12.5	17.8	22.8	27.7	32.8
11	3.1	6.3	12.5	17.8	22.8	27.9	32.9
12	3.2	6.4	12.6	17.9	22.8	27.8	32.8
13	3.1	6.4	12.5	17.9	22.9	27.8	32.8
14	3.2	6.4	12.6	17.9	22.8	27.8	32.8
15	3.1	6.3	12.4	17.8	22.7	27.7	32.9
16	3.1	6.3	12.5	17.8	22.7	27.8	32.7
17	3.1	6.3	12.5	17.8	22.8	27.8	32.7
18	3.2	6.4	12.6	17.9	22.8	27.9	32.8
19	3.1	6.4	12.6	17.9	22.9	27.8	32.8
20	3.2	6.4	12.5	17.9	22.8	27.8	32.9
Sum	62.6	127.0	250.5	357.1	455.9	556.2	656.6
Average	3.13	6.35	12.525	17.855	22.795	27.81	32.83
SD	0.04	0.05	0.06	0.04	0.05	0.06	0.06

<u>Replicate-1</u>

Table 5.42: 3500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.8	5.8	11.5	16.7	21.5	26.1	30.7
2	2.8	5.8	11.5	16.7	21.5	26.2	30.8
3	2.9	5.8	11.6	16.7	21.4	26.1	30.7
4	2.9	5.9	11.6	16.8	21.6	26.2	30.8
5	2.9	5.9	11.6	16.8	21.5	26.2	30.7
6	2.8	5.7	11.5	16.7	21.4	26.1	30.6
7	2.8	5.8	11.5	16.7	21.4	26.1	30.7
8	2.8	5.8	11.6	16.7	21.5	26.2	30.8
9	2.9	5.8	11.6	16.8	21.5	26.2	30.7
10	2.9	5.8	11.5	16.7	21.5	26.1	30.6
11	2.9	5.8	11.5	16.7	21.4	26.1	30.7
12	2.8	5.7	11.5	16.8	21.5	26.2	30.8
13	2.8	5.8	11.6	16.8	21.5	26.1	30.7
14	2.8	5.7	11.5	16.7	21.4	26.1	30.7
15	2.9	5.9	11.6	16.9	21.6	26.3	30.9
16	2.9	5.8	11.6	16.8	21.6	26.2	30.8
17	2.9	5.8	11.5	16.7	21.5	26.2	30.8
18	2.8	5.8	11.6	16.8	21.5	26.2	30.7
19	2.9	5.8	11.5	16.7	21.5	26.2	30.8
20	2.9	5.9	11.6	16.8	21.6	26.3	30.9
Sum	57.1	116.1	231	335	429.9	523.4	614.9
Average	2.855	5.805	11.55	16.75	21.495	26.17	30.745
SD	0.04	0.05	0.05	0.05	0.06	0.06	0.08

Replicate-1

Table 5.43: 4000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.9	9.5	14.5	19.0	23.5	27.7
2	2.4	4.8	9.4	14.5	19.1	23.5	27.8
3	2.4	4.9	9.5	14.5	19.0	23.5	27.7
4	2.5	5.0	9.5	14.6	19.1	23.6	27.9
5	2.4	4.9	9.4	14.5	19.1	23.6	27.8
6	2.5	5.0	9.5	14.6	19.2	23.7	27.9
7	2.5	4.9	9.5	14.5	19.1	23.7	27.9
8	2.5	4.9	9.4	14.5	19.0	23.5	27.8
9	2.4	4.8	9.4	14.6	19.1	23.7	27.9
10	2.5	5.0	9.5	14.5	19.1	23.6	27.8
11	2.4	4.9	9.5	14.6	19.2	23.7	27.9
12	2.4	4.8	9.4	14.4	19.0	23.5	27.8
13	2.5	4.9	9.4	14.5	19.0	23.6	27.9
14	2.4	4.8	9.4	14.4	19.0	23.6	27.9
15	2.5	5.0	9.5	14.5	19.1	23.7	27.9
16	2.5	4.9	9.4	14.5	19.1	23.6	27.9
17	2.5	4.9	9.5	14.6	19.2	23.7	27.9
18	2.4	4.9	9.5	14.6	19.2	23.7	27.9
19	2.4	4.8	9.4	14.5	19.1	23.6	27.9
20	2.4	4.9	9.5	14.5	19.1	23.6	27.9
Sum	48.9	97.9	189.1	290.4	381.8	472.2	557.1
Average	2.445	4.895	9.455	14.52	19.09	23.61	27.855
SD	0.04	0.06	0.04	0.06	0.07	0.07	0.06

<u>Replicate-1</u>

Table 5.44: 4500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.6	9.0	14.0	18.2	22.3	26.3
2	2.3	4.7	9.1	14.2	18.3	22.3	26.4
3	2.3	4.6	9.1	14.1	18.2	22.3	26.3
4	2.4	4.7	9.2	14.2	18.4	22.4	26.3
5	2.4	4.7	9.1	14.2	18.3	22.4	26.4
6	2.3	4.7	9.1	14.2	18.3	22.3	26.3
7	2.4	4.7	9.2	14.1	18.3	22.3	26.4
8	2.4	4.7	9.2	14.2	18.4	22.4	26.4
9	2.3	4.6	9.1	14.2	18.4	22.3	26.4
10	2.3	4.6	9.1	14.1	18.3	22.3	26.4
11	2.4	4.7	9.1	14.2	18.3	22.4	26.4
12	2.3	4.6	9.0	14.0	18.2	22.3	26.3
13	2.3	4.7	9.1	14.1	18.3	22.3	26.4
14	2.4	4.8	9.2	14.2	18.4	22.5	26.4
15	2.4	4.7	9.1	14.2	18.4	22.4	26.3
16	2.3	4.7	9.1	14.2	18.3	22.4	26.4
17	2.3	4.6	9.1	14.1	18.3	22.3	26.3
18	2.4	4.7	9.1	14.0	18.2	22.3	26.3
19	2.3	4.6	9.0	14.0	18.2	22.3	26.4
20	2.3	4.6	9.0	14.0	18.3	22.4	26.4
Sum	46.8	93.3	182.0	282.5	366.0	446.9	527.2
Average	2.34	4.665	9.1	14.125	18.3	22.345	26.36
SD	0.04	0.05	0.06	0.08	0.07	0.05	0.04

Replicate-1

Table 5.45: 5000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.1	4.0	7.7	12.5	16.3	20.3	24.3
2	2.2	4.0	7.7	12.5	16.3	20.4	24.4
3	2.2	4.1	7.8	12.5	16.3	20.3	24.3
4	2.1	4.0	7.8	12.6	16.4	20.3	24.3
5	2.2	4.0	7.8	12.6	16.3	20.3	24.2
6	2.2	4.0	7.9	12.6	16.3	20.4	24.2
7	2.2	4.1	7.8	12.6	16.4	20.4	24.4
8	2.2	4.1	7.9	12.7	16.4	20.4	24.3
9	2.3	4.1	7.9	12.7	16.5	20.4	24.4
10	2.2	4.0	7.7	12.5	16.3	20.3	24.3
11	2.2	4.0	7.8	12.5	16.4	20.5	24.4
12	2.1	4.0	7.8	12.5	16.3	20.5	24.5
13	2.2	4.0	7.9	12.6	16.4	20.4	24.4
14	2.1	4.1	7.9	12.6	16.3	20.5	24.4
15	2.2	4.1	7.8	12.6	16.3	20.4	24.4
16	2.1	4.0	7.7	12.5	16.3	20.3	24.3
17	2.2	4.0	7.8	12.6	16.4	20.3	24.3
18	2.2	4.1	7.8	12.6	16.4	20.4	24.3
19	2.1	4.2	7.9	12.7	16.5	20.4	24.4
20	2.2	4.1	7.8	12.5	16.3	20.3	24.3
Sum	43.5	81.0	156.2	251.5	327.1	407.5	486.8
Average	2.175	4.05	7.81	12.575	16.355	20.375	24.34
SD	0.05	0.05	0.07	0.06	0.06	0.06	0.07

<u>Replicate-2</u>

Table 5.46: *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours without any sound treatment

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.3	8.2	13.1	17.0	21.2	25.2
2	2.2	4.2	8.1	13.0	17.0	21.1	25.2
3	2.2	4.3	8.2	13.1	17.1	21.3	25.3
4	2.3	4.3	8.2	13.2	17.2	21.3	25.3
5	2.2	4.2	8.1	13.1	17.2	21.2	25.2
6	2.3	4.3	8.2	13.1	17.1	21.2	25.3
7	2.1	4.2	8.3	13.1	17.2	21.3	25.3
8	2.2	4.3	8.3	13.2	17.2	21.3	25.3
9	2.3	4.3	8.2	13.1	17.1	21.2	25.3
10	2.2	4.2	8.2	13.1	17.1	21.2	25.3
11	2.3	4.2	8.1	13.0	17.1	21.2	25.3
12	2.2	4.2	8.2	13.1	17.2	21.3	25.3
13	2.2	4.3	8.2	13.1	17.1	21.2	25.3
14	2.3	4.3	8.2	13.0	17.0	21.2	25.2
15	2.3	4.3	8.2	13.1	17.2	21.3	25.3
16	2.2	4.2	8.1	13.0	17.0	21.2	25.3
17	2.2	4.3	8.2	13.1	17.2	21.3	25.3
18	2.3	4.3	8.3	13.2	17.2	21.3	25.3
19	2.1	4.2	8.2	13.2	17.2	21.2	25.3
20	2.2	4.2	8.1	13.0	17.1	21.2	25.2
Sum	44.6	85.1	163.8	261.9	342.5	424.7	505.5
Average	2.23	4.255	8.19	13.095	17.125	21.235	25.275
SD	0.06	0.04	0.06	0.06	0.07	0.05	0.04

<u>Replicate-2</u>

Table 5.47: 500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 Hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.4	8.3	13.3	17.3	21.4	25.5
2	2.4	4.4	8.4	13.3	17.3	21.5	25.6
3	2.3	4.4	8.4	13.4	17.3	21.4	25.6
4	2.3	4.3	8.3	13.3	17.4	21.4	25.6
5	2.3	4.4	8.3	13.4	17.4	21.4	25.6
6	2.4	4.4	8.3	13.3	17.3	21.4	25.6
7	2.3	4.3	8.3	13.3	17.3	21.3	25.5
8	2.3	4.3	8.3	13.3	17.4	21.4	25.6
9	2.3	4.3	8.3	13.4	17.4	21.5	25.6
10	2.3	4.3	8.4	13.4	17.3	21.3	25.5
11	2.2	4.3	8.3	13.2	17.3	21.4	25.5
12	2.3	4.4	8.4	13.3	17.3	21.3	25.5
13	2.2	4.3	8.3	13.3	17.2	21.3	25.5
14	2.3	4.3	8.3	13.3	17.2	21.3	25.4
15	2.3	4.4	8.4	13.4	17.3	21.3	25.4
16	2.3	4.3	8.3	13.3	17.4	21.4	25.5
17	2.4	4.4	8.3	13.2	17.3	21.4	25.6
18	2.3	4.4	8.4	13.3	17.3	21.4	25.6
19	2.3	4.3	8.3	13.3	17.4	21.4	25.6
20	2.2	4.3	8.3	13.2	17.3	21.3	25.5
Sum	46.0	86.9	166.6	266.2	346.4	427.5	510.8
Average	2.3	4.345	8.33	13.31	17.32	21.375	25.54
SD	0.05	0.04	0.04	0.06	0.06	0.06	0.06

Replicate-2

Table 5.48: 1000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	4.9	9.7	14.9	19.2	23.7	28.1
2	2.5	4.9	9.7	14.9	19.1	23.6	28.0
3	2.5	4.8	9.6	14.8	19.1	23.6	27.9
4	2.5	4.9	9.6	14.8	19.1	23.6	28.0
5	2.4	4.8	9.6	14.8	19.1	23.6	28.0
6	2.4	4.8	9.6	14.8	19.2	23.7	28.0
7	2.4	4.8	9.6	14.8	19.1	23.6	27.9
8	2.5	4.9	9.6	14.8	19.2	23.7	28.0
9	2.4	4.8	9.6	14.8	19.1	23.6	27.9
10	2.5	4.8	9.6	14.8	19.1	23.7	28.0
11	2.5	4.9	9.7	14.9	19.2	23.6	28.0
12	2.4	4.8	9.6	14.8	19.2	23.7	28.0
13	2.5	4.9	9.7	14.9	19.2	23.7	28.1
14	2.5	4.9	9.7	14.9	19.2	23.7	28.0
15	2.5	4.9	9.6	14.8	19.1	23.6	27.9
16	2.5	4.9	9.7	14.9	19.2	23.7	28.0
17	2.4	4.8	9.5	14.8	19.1	23.6	28.0
18	2.5	4.8	9.5	14.7	19.1	23.6	28.0
19	2.5	4.8	9.6	14.8	19.2	23.7	28.0
20	2.5	4.8	9.5	14.7	19.1	23.6	28.0
Sum	49.4	96.9	192.3	296.4	382.9	472.9	559.8
Average	2.47	4.845	9.615	14.82	19.145	23.645	27.99
SD	0.04	0.04	0.06	0.06	0.04	0.04	0.05

Replicate-2

Table 5.49: 1500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.8	5.6	10.9	16.0	20.7	25.2	29.7
2	2.8	5.6	10.9	15.9	20.6	25.2	29.6
3	2.8	5.5	10.7	15.8	20.5	25.1	29.6
4	2.8	5.6	10.8	15.8	20.5	25.1	29.6
5	2.8	5.6	10.8	15.8	20.5	25.1	29.5
6	2.7	5.5	10.7	15.9	20.5	25.0	29.4
7	2.8	5.6	10.9	16.0	20.7	25.2	29.7
8	2.7	5.5	10.8	15.9	20.6	25.1	29.5
9	2.8	5.6	10.8	15.8	20.6	25.1	29.6
10	2.8	5.5	10.8	15.9	20.5	25.0	29.5
11	2.7	5.5	10.7	15.9	20.6	25.1	29.5
12	2.8	5.5	10.8	15.8	20.5	25.0	29.4
13	2.7	5.5	10.8	15.9	20.5	25.1	29.5
14	2.8	5.6	10.9	16.0	20.6	25.1	29.6
15	2.8	5.6	10.8	15.9	20.5	25.0	29.6
16	2.7	5.6	10.9	16.0	20.6	25.1	29.6
17	2.8	5.6	10.8	16.0	20.6	25.2	29.6
18	2.7	5.5	10.7	15.8	20.5	25.1	29.6
19	2.8	5.6	10.8	15.9	20.5	25.0	29.5
20	2.8	5.5	10.8	15.8	20.5	25.1	29.6
Sum	55.4	111.1	216.1	317.8	411.1	501.9	591.2
Average	2.77	5.555	10.805	15.89	20.555	25.095	29.56
SD	0.04	0.04	0.06	0.07	0.06	0.06	0.08

<u>Replicate-2</u>

Table 5.50: 2000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.1	6.1	12.2	17.6	22.5	27.3	32.2
2	3.1	6.1	12.2	17.5	22.4	27.3	32.1
3	3.0	6.0	12.0	17.4	22.3	27.2	32.1
4	3.0	6.1	12.2	17.6	22.4	27.3	32.2
5	3.1	6.2	12.3	17.6	22.4	27.2	32.0
6	3.0	6.1	12.1	17.5	22.3	27.1	32.0
7	3.1	6.1	12.2	17.6	22.4	27.3	32.2
8	3.1	6.1	12.2	17.5	22.3	27.2	32.1
9	3.0	6.0	12.1	17.5	22.3	27.2	32.0
10	3.0	6.0	12.0	17.4	22.3	27.1	32.0
11	3.1	6.1	12.1	17.5	22.3	27.1	31.9
12	3.1	6.0	12.0	17.4	22.2	27.1	32.0
13	3.1	6.1	12.1	17.6	22.4	27.2	32.1
14	3.1	6.1	12.2	17.5	22.3	27.1	32.0
15	3.1	6.1	12.2	17.6	22.4	27.2	32.1
16	3.0	6.1	12.2	17.5	22.3	27.1	32.0
17	3.0	6.0	12.0	17.6	22.4	27.2	32.0
18	3.1	6.2	12.3	17.6	22.4	27.2	32.1
19	3.0	6.1	12.2	17.6	22.5	27.3	32.2
20	3.0	6.0	12.0	17.4	22.3	27.1	32.2
Sum	61.1	121.6	242.8	350.5	447.1	543.8	641.5
Average	3.055	6.08	12.14	17.525	22.355	27.19	32.075
SD	0.04	0.06	0.09	0.07	0.07	0.07	0.08

<u>Replicate-2</u>

Table 5.51: 2500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.4	6.8	13.7	19.4	24.4	29.5	34.5
2	3.4	6.8	13.7	19.4	24.5	29.5	34.4
3	3.3	6.7	13.6	19.4	24.4	29.4	34.4
4	3.3	6.7	13.6	19.3	24.4	29.4	34.3
5	3.3	6.7	13.7	19.4	24.4	29.3	34.4
6	3.4	6.9	13.8	19.5	24.4	29.4	34.4
7	3.3	6.6	13.6	19.3	24.3	29.3	34.3
8	3.4	6.8	13.6	19.4	24.4	29.4	34.3
9	3.3	6.6	13.6	19.3	24.4	29.4	34.3
10	3.4	6.8	13.7	19.4	24.4	29.3	34.4
11	3.3	6.7	13.6	19.4	24.4	29.3	34.3
12	3.3	6.7	13.6	19.4	24.5	29.5	34.5
13	3.3	6.8	13.6	19.3	24.4	29.5	34.5
14	3.4	6.9	13.7	19.5	24.5	29.5	34.5
15	3.4	6.8	13.6	19.3	24.3	29.3	34.5
16	3.4	6.9	13.7	19.5	24.4	29.4	34.5
17	3.3	6.7	13.6	19.3	24.3	29.4	34.4
18	3.3	6.6	13.5	19.3	24.3	29.3	34.4
19	3.3	6.7	13.6	19.4	24.4	29.4	34.4
20	3.4	6.9	13.7	19.5	24.5	29.5	34.5
Sum	66.9	135.1	272.8	387.7	488.0	588.0	688.2
Average	3.345	6.755	13.64	19.385	24.4	29.4	34.41
SD	0.04	0.09	0.06	0.07	0.06	0.07	0.07

<u>Replicate-2</u>

Table 5.52: 3000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.2	6.4	12.6	17.9	22.9	27.9	32.9
2	3.2	6.4	12.6	17.9	22.9	27.8	32.8
3	3.2	6.4	12.6	17.8	22.8	27.8	32.8
4	3.1	6.3	12.5	17.8	22.7	27.7	32.8
5	3.2	6.4	12.6	17.9	22.8	27.8	32.8
6	3.2	6.4	12.5	17.8	22.7	27.7	32.8
7	3.1	6.3	12.5	17.9	22.9	27.9	32.9
8	3.1	6.3	12.5	17.8	22.8	27.8	32.8
9	3.1	6.3	12.5	17.9	22.9	27.8	32.9
10	3.2	6.4	12.5	17.8	22.8	27.8	32.9
11	3.1	6.3	12.6	17.8	22.8	27.9	32.8
12	3.2	6.4	12.6	17.9	22.8	27.8	32.8
13	3.1	6.3	12.5	17.8	22.8	27.8	32.8
14	3.2	6.4	12.6	17.9	22.8	27.7	32.7
15	3.2	6.4	12.5	17.8	22.7	27.7	32.8
16	3.1	6.3	12.6	17.9	22.9	27.8	32.8
17	3.1	6.3	12.5	17.8	22.8	27.9	32.8
18	3.2	6.4	12.6	17.9	22.9	27.9	32.9
19	3.1	6.3	12.5	17.8	22.7	27.8	32.8
20	3.2	6.4	12.6	17.9	22.8	27.9	32.8
Sum	63.1	127.1	251.0	357.0	456.2	556.2	656.4
Average	3.155	6.355	12.55	17.85	22.81	27.81	32.82
SD	0.04	0.04	0.05	0.05	0.07	0.07	0.05

Replicate-2

Table 5.53: 3500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.9	5.9	11.6	16.8	21.5	26.2	30.7
2	2.8	5.8	11.5	16.8	21.6	26.2	30.7
3	2.9	5.8	11.6	16.8	21.6	26.3	30.9
4	2.9	5.9	11.6	16.8	21.6	26.2	30.8
5	2.9	5.9	11.7	16.9	21.6	26.3	30.8
6	2.8	5.8	11.6	16.8	21.5	26.2	30.8
7	2.8	5.8	11.5	16.7	21.4	26.2	30.7
8	2.8	5.8	11.6	16.8	21.6	26.3	30.8
9	2.9	5.8	11.6	16.7	21.5	26.2	30.8
10	2.9	5.8	11.5	16.7	21.5	26.2	30.7
11	2.9	5.9	11.7	16.7	21.5	26.3	30.9
12	2.9	5.8	11.5	16.7	21.4	26.2	30.8
13	2.9	5.9	11.6	16.8	21.5	26.2	30.7
14	2.8	5.8	11.6	16.7	21.4	26.2	30.8
15	2.9	5.9	11.6	16.8	21.6	26.3	30.9
16	2.9	5.8	11.6	16.8	21.5	26.2	30.8
17	2.9	5.9	11.7	16.9	21.6	26.3	30.8
18	2.8	5.8	11.6	16.8	21.5	26.2	30.8
19	2.8	5.8	11.5	16.7	21.5	26.2	30.8
20	2.8	5.9	11.6	16.8	21.6	26.3	30.8
Sum	57.2	116.8	231.8	335.5	430.5	524.7	615.8
Average	2.86	5.84	11.59	16.775	21.525	26.235	30.79
SD	0.04	0.04	0.06	0.06	0.06	0.04	0.06

Replicate-2

Table 5.54: 4000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	5.0	9.5	14.6	19.1	23.6	27.9
2	2.4	4.8	9.4	14.5	19.1	23.6	27.8
3	2.5	5.0	9.5	14.5	19.0	23.5	27.8
4	2.5	5.0	9.5	14.5	19.1	23.6	27.9
5	2.4	4.9	9.4	14.5	19.1	23.6	27.8
6	2.5	5.0	9.5	14.5	19.0	23.5	27.8
7	2.5	4.9	9.5	14.5	19.1	23.6	27.9
8	2.5	4.9	9.5	14.6	19.1	23.5	27.8
9	2.4	4.8	9.4	14.6	19.1	23.6	27.8
10	2.5	5.0	9.5	14.5	19.1	23.6	27.8
11	2.4	4.9	9.5	14.6	19.1	23.5	27.7
12	2.4	4.8	9.4	14.5	19.0	23.5	27.8
13	2.4	4.9	9.4	14.4	19.0	23.5	27.7
14	2.4	4.9	9.4	14.6	19.1	23.6	27.9
15	2.5	5.0	9.5	14.5	19.0	23.6	27.8
16	2.5	4.9	9.5	14.6	19.1	23.6	27.9
17	2.5	5.0	9.5	14.4	19.0	23.5	27.8
18	2.4	4.9	9.5	14.5	19.1	23.6	27.9
19	2.5	4.9	9.5	14.6	19.2	23.6	27.8
20	2.5	4.9	9.5	14.5	19.1	23.6	27.9
Sum	49.2	98.4	189.4	290.5	381.5	471.3	556.5
Average	2.46	4.92	9.47	14.525	19.075	23.565	27.825
SD	0.04	0.06	0.04	0.06	0.05	0.04	0.06

Replicate-2

Table 5.55: 4500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.8	9.2	14.1	18.3	22.3	26.4
2	2.4	4.8	9.2	14.2	18.4	22.5	26.4
3	2.3	4.7	9.1	14.0	18.2	22.3	26.3
4	2.4	4.8	9.2	14.2	18.3	22.4	26.4
5	2.3	4.7	9.2	14.1	18.3	22.3	26.4
6	2.4	4.7	9.1	14.2	18.4	22.4	26.4
7	2.4	4.8	9.2	14.2	18.4	22.3	26.4
8	2.4	4.7	9.1	14.2	18.4	22.4	26.4
9	2.3	4.6	9.0	14.1	18.2	22.3	26.4
10	2.3	4.6	9.0	14.1	18.3	22.3	26.3
11	2.4	4.8	9.2	14.2	18.4	22.4	26.4
12	2.3	4.6	9.0	14.0	18.2	22.3	26.3
13	2.3	4.7	9.1	14.0	18.3	22.4	26.4
14	2.4	4.8	9.2	14.2	18.4	22.4	26.4
15	2.3	4.7	9.0	14.2	18.4	22.4	26.5
16	2.4	4.7	9.2	14.1	18.3	22.4	26.4
17	2.3	4.7	9.0	14.1	18.4	22.4	26.4
18	2.4	4.7	9.1	14.1	18.2	22.3	26.4
19	2.3	4.6	9.0	14.1	18.3	22.4	26.4
20	2.4	4.8	9.1	14.2	18.4	22.5	26.5
Sum	47.1	94.3	182.2	282.6	366.5	447.4	527.9
Average	2.355	4.715	9.11	14.13	18.325	22.37	26.395
SD	0.04	0.07	0.08	0.07	0.07	0.06	0.04

Replicate-2

Table 5.56: 5000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.1	7.8	12.6	16.4	20.4	24.4
2	2.1	4.0	7.7	12.5	16.3	20.4	24.3
3	2.1	4.1	7.9	12.6	16.5	20.4	24.3
4	2.1	4.1	7.8	12.6	16.4	20.5	24.4
5	2.2	4.0	7.8	12.5	16.3	20.4	24.4
6	2.2	4.2	7.9	12.7	16.5	20.5	24.5
7	2.2	4.1	7.9	12.7	16.4	20.4	24.4
8	2.1	4.1	7.9	12.6	16.4	20.3	24.4
9	2.2	4.2	7.9	12.6	16.5	20.4	24.4
10	2.1	4.0	7.7	12.5	16.3	20.3	24.3
11	2.2	4.1	7.8	12.6	16.3	20.4	24.3
12	2.1	4.0	7.7	12.5	16.3	20.4	24.3
13	2.1	4.0	7.8	12.6	16.4	20.4	24.4
14	2.1	4.1	7.9	12.7	16.5	20.5	24.4
15	2.2	4.0	7.7	12.5	16.3	20.4	24.3
16	2.1	4.0	7.8	12.5	16.4	20.4	24.3
17	2.1	4.1	7.8	12.6	16.4	20.3	24.3
18	2.2	4.2	7.9	12.7	16.5	20.4	24.3
19	2.2	4.2	7.9	12.7	16.5	20.5	24.4
20	2.1	4.0	7.8	12.6	16.4	20.4	24.4
Sum	42.9	81.6	156.4	251.9	328	408.1	487.2
Average	2.145	4.08	7.82	12.595	16.4	20.405	24.36
SD	0.04	0.07	0.07	0.07	0.07	0.05	0.05

Replicate-3

Table 5.57: *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours without any audible sound treatment

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.2	8.0	12.9	17.0	21.1	25.2
2	2.3	4.2	7.9	12.9	16.9	21.0	25.2
3	2.2	4.2	8.0	12.9	17.0	21.1	25.1
4	2.1	4.2	8.0	13.0	17.0	21.2	25.2
5	2.2	4.2	8.0	13.0	16.9	21.1	25.2
6	2.2	4.1	7.9	13.0	16.9	21.1	25.3
7	2.2	4.2	8.0	12.9	16.9	21.1	25.2
8	2.2	4.1	7.9	12.9	17.0	21.2	25.2
9	2.1	4.2	8.1	13.0	17.0	21.1	25.1
10	2.3	4.2	8.1	13.1	17.0	21.2	25.2
11	2.2	4.2	8.1	13.0	17.0	21.2	25.2
12	2.1	4.0	8.0	12.9	16.9	21.0	25.2
13	2.2	4.2	8.1	12.9	16.9	21.0	25.2
14	2.2	4.1	8.0	12.9	17.0	21.2	25.2
15	2.2	4.2	8.1	12.9	17.0	21.2	25.1
16	2.2	4.1	8.1	13.0	17.0	21.2	25.3
17	2.2	4.2	8.2	13.1	17.0	21.1	25.2
18	2.2	4.1	7.9	12.9	16.9	21.1	25.1
19	2.1	4.1	7.9	13.0	17.0	21.2	25.3
20	2.2	4.1	8.0	12.9	17.0	21.2	25.3
Sum	43.8	83.1	160.3	259.1	339.3	422.6	504.0
Average	2.19	4.155	8.015	12.955	16.965	21.13	25.2
SD	0.05	0.05	0.08	0.06	0.04	0.07	0.06

Replicate-3

Table 5.58: 500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.2	8.2	13.2	17.2	21.3	25.4
2	2.2	4.2	8.2	13.2	17.2	21.3	25.5
3	2.3	4.3	8.3	13.3	17.3	21.3	25.5
4	2.3	4.3	8.2	13.2	17.2	21.3	25.4
5	2.3	4.4	8.3	13.3	17.3	21.4	25.5
6	2.2	4.3	8.3	13.3	17.2	21.3	25.5
7	2.3	4.3	8.3	13.3	17.3	21.3	25.5
8	2.3	4.3	8.3	13.4	17.3	21.3	25.5
9	2.2	4.3	8.3	13.4	17.3	21.4	25.5
10	2.3	4.3	8.2	13.3	17.3	21.3	25.5
11	2.2	4.2	8.3	13.3	17.2	21.3	25.5
12	2.3	4.3	8.3	13.4	17.3	21.3	25.4
13	2.2	4.2	8.2	13.3	17.2	21.3	25.5
14	2.3	4.3	8.3	13.4	17.4	21.4	25.5
15	2.3	4.3	8.2	13.2	17.3	21.3	25.4
16	2.3	4.3	8.3	13.3	17.3	21.4	25.5
17	2.2	4.2	8.2	13.3	17.2	21.3	25.5
18	2.3	4.3	8.3	13.3	17.3	21.3	25.4
19	2.2	4.2	8.3	13.3	17.2	21.3	25.4
20	2.2	4.2	8.2	13.2	17.2	21.3	25.5
Sum	45.1	85.4	165.2	265.9	345.2	426.4	509.4
Average	2.255	4.27	8.26	13.295	17.26	21.32	25.47
SD	0.04	0.05	0.04	0.06	0.05	0.04	0.04

Replicate-3

Table 5.59: 1000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.7	9.5	14.8	19.1	23.6	28.0
2	2.4	4.7	9.5	14.8	19.1	23.6	28.0
3	2.4	4.8	9.6	14.8	19.2	23.7	28.0
4	2.4	4.8	9.5	14.8	19.2	23.6	27.9
5	2.4	4.7	9.5	14.7	19.0	23.5	27.9
6	2.4	4.7	9.5	14.8	19.2	23.7	28.0
7	2.4	4.8	9.5	14.7	19.1	23.6	27.9
8	2.3	4.7	9.5	14.8	19.1	23.7	28.0
9	2.4	4.7	9.5	14.7	19.1	23.6	27.9
10	2.3	4.7	9.5	14.8	19.2	23.6	27.9
11	2.4	4.8	9.6	14.8	19.2	23.6	27.9
12	2.4	4.7	9.5	14.7	19.1	23.6	27.9
13	2.4	4.8	9.6	14.8	19.1	23.7	28.0
14	2.5	4.8	9.5	14.7	19.0	23.5	27.9
15	2.3	4.7	9.5	14.8	19.1	23.6	27.9
16	2.4	4.7	9.5	14.8	19.0	23.6	27.9
17	2.5	4.8	9.6	14.8	19.2	23.7	28.0
18	2.3	4.7	9.5	14.8	19.1	23.6	27.9
19	2.4	4.7	9.5	14.8	19.2	23.7	28.0
20	2.4	4.7	9.5	14.8	19.1	23.6	27.9
Sum	47.7	94.7	190.4	295.5	382.4	472.4	558.8
Average	2.385	4.735	9.52	14.775	19.12	23.62	27.94
SD	0.05	0.04	0.04	0.04	0.06	0.06	0.04

<u>**Replicate-3**</u>

Table 5.60: 1500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 1500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.7	5.4	10.7	15.8	20.4	24.9	29.4
2	2.7	5.5	10.8	15.9	20.5	25.0	29.5
3	2.6	5.4	10.7	15.8	20.5	25.0	29.5
4	2.7	5.4	10.7	15.8	20.5	25.1	29.6
5	2.6	5.4	10.7	15.7	20.4	24.9	29.5
6	2.7	5.4	10.7	15.8	20.5	25.0	29.6
7	2.7	5.4	10.6	15.7	20.4	24.9	29.5
8	2.7	5.4	10.6	15.7	20.4	24.9	29.5
9	2.6	5.4	10.7	15.8	20.5	25.1	29.6
10	2.7	5.5	10.8	15.9	20.6	25.1	29.6
11	2.7	5.4	10.7	15.7	20.4	24.9	29.5
12	2.7	5.5	10.8	15.8	20.5	25.0	29.5
13	2.7	5.4	10.7	15.7	20.4	24.9	29.4
14	2.7	5.4	10.6	15.7	20.4	24.9	29.4
15	2.6	5.4	10.7	15.8	20.5	25.0	29.5
16	2.7	5.4	10.7	15.8	20.5	24.9	29.4
17	2.7	5.5	10.7	15.8	20.5	25.0	29.5
18	2.7	5.4	10.7	15.7	20.4	24.9	29.5
19	2.6	5.4	10.6	15.7	20.4	24.9	29.4
20	2.7	5.4	10.7	15.8	20.5	25.0	29.5
Sum	53.5	108.4	213.9	315.4	409.2	499.3	589.9
Average	2.675	5.42	10.695	15.77	20.46	24.965	29.495
SD	0.04	0.04	0.05	0.06	0.05	0.07	0.06

Replicate-3

Table 5.61: 2000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.0	6.0	12.0	17.4	22.2	27.1	32.0
2	3.0	6.0	12.1	17.5	22.3	27.2	32.0
3	3.0	6.1	12.2	17.5	22.2	27.1	31.9
4	3.1	6.2	12.2	17.5	22.3	27.2	32.0
5	3.0	6.0	12.0	17.4	22.2	27.1	32.0
6	3.0	6.0	12.0	17.4	22.2	27.0	31.9
7	3.0	6.1	12.2	17.5	22.2	27.1	31.9
8	3.0	6.1	12.2	17.6	22.3	27.2	32.0
9	3.0	6.1	12.2	17.6	22.3	27.2	32.1
10	3.1	6.1	12.2	17.5	22.2	27.0	32.0
11	3.0	6.0	12.1	17.5	22.3	27.2	32.0
12	3.1	6.2	12.2	17.6	22.4	27.2	32.0
13	3.0	6.1	12.2	17.5	22.2	27.1	31.9
14	3.0	6.1	12.2	17.6	22.3	27.2	32.0
15	3.1	6.2	12.2	17.5	22.3	27.1	31.9
16	3.0	6.0	12.1	17.5	22.2	27.1	31.9
17	3.0	6.0	12.0	17.4	22.2	27.1	31.9
18	3.0	6.0	12.0	17.4	22.2	27.1	32.0
19	3.0	6.1	12.2	17.6	22.3	27.1	32.0
20	3.1	6.2	12.2	17.6	22.4	27.2	32.0
Sum	60.5	121.6	242.7	350.1	445.2	542.6	639.4
Average	3.025	6.08	12.135	17.505	22.26	27.13	31.97
SD	0.04	0.07	0.08	0.07	0.06	0.06	0.05

Replicate-3

Table 5.62: 2500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 2500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.3	6.6	13.5	19.4	24.5	29.4	34.4
2	3.3	6.7	13.6	19.5	24.4	29.4	34.4
3	3.4	6.8	13.7	19.5	24.4	29.4	34.5
4	3.3	6.7	13.6	19.4	24.4	29.5	34.5
5	3.3	6.7	13.6	19.5	24.5	29.4	34.5
6	3.3	6.8	13.6	19.5	24.5	29.5	34.5
7	3.4	6.8	13.6	19.4	24.4	29.4	34.4
8	3.4	6.8	13.7	19.5	24.5	29.5	34.5
9	3.3	6.7	13.6	19.5	24.5	29.5	34.4
10	3.3	6.8	13.7	19.5	24.4	29.5	34.5
11	3.4	6.8	13.7	19.4	24.5	29.4	34.4
12	3.3	6.7	13.6	19.4	24.4	29.3	34.4
13	3.3	6.7	13.7	19.4	24.5	29.5	34.5
14	3.3	6.7	13.6	19.4	24.5	29.4	34.4
15	3.3	6.7	13.6	19.4	24.4	29.5	34.5
16	3.4	6.8	13.6	19.5	24.4	29.4	34.5
17	3.3	6.7	13.6	19.4	24.4	29.4	34.4
18	3.3	6.7	13.6	19.4	24.4	29.4	34.4
19	3.3	6.7	13.6	19.4	24.4	29.4	34.4
20	3.3	6.6	13.5	19.4	24.5	29.5	34.4
Sum	66.5	134.5	272.3	388.8	488.9	588.7	688.9
Average	3.325	6.725	13.615	19.44	24.445	29.435	34.445
SD	0.04	0.06	0.05	0.04	0.04	0.05	0.04

Replicate-3

Table 5.63: 3000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.2	6.4	12.6	17.9	22.8	27.8	32.8
2	3.1	6.3	12.5	17.8	22.7	27.7	32.8
3	3.2	6.4	12.6	17.8	22.8	27.8	32.8
4	3.1	6.3	12.5	17.8	22.7	27.8	32.7
5	3.2	6.4	12.5	17.8	22.8	27.8	32.8
6	3.1	6.3	12.5	17.9	22.8	27.9	32.9
7	3.1	6.4	12.6	17.9	22.8	27.9	32.8
8	3.1	6.3	12.5	17.8	22.7	27.8	32.9
9	3.1	6.3	12.5	17.8	22.8	27.8	32.9
10	3.2	6.4	12.6	17.9	22.8	27.9	32.8
11	3.1	6.3	12.5	17.8	22.8	27.9	32.9
12	3.2	6.4	12.6	17.9	22.8	27.8	32.8
13	3.1	6.3	12.5	17.8	22.7	27.8	32.8
14	3.2	6.4	12.6	17.9	22.8	27.9	32.9
15	3.1	6.3	12.5	17.9	22.8	27.7	32.8
16	3.1	6.3	12.5	17.8	22.7	27.8	32.8
17	3.1	6.3	12.5	17.8	22.7	27.9	32.9
18	3.2	6.4	12.6	17.9	22.8	27.9	32.9
19	3.1	6.3	12.5	17.8	22.7	27.8	32.8
20	3.1	6.3	12.5	17.8	22.7	27.9	32.9
Sum	62.7	126.8	250.7	356.8	455.2	556.6	656.7
Average	3.135	6.34	12.535	17.84	22.76	27.83	32.835
SD	0.04	0.04	0.04	0.04	0.04	0.06	0.05

Replicate-3

Table 5.64: 3500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 3500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.8	5.8	11.5	16.8	21.6	26.2	30.7
2	2.8	5.8	11.6	16.8	21.6	26.3	30.8
3	2.9	5.9	11.6	16.9	21.7	26.3	30.9
4	2.9	5.8	11.6	16.8	21.5	26.2	30.8
5	2.7	5.7	11.5	16.8	21.6	26.2	30.8
6	2.8	5.8	11.6	16.8	21.6	26.2	30.7
7	2.8	5.8	11.5	16.8	21.6	26.3	30.8
8	2.8	5.7	11.4	16.7	21.5	26.2	30.8
9	2.9	5.8	11.6	16.8	21.5	26.1	30.8
10	2.7	5.7	11.5	16.7	21.4	26.1	30.8
11	2.9	5.9	11.6	16.8	21.5	26.2	30.9
12	2.9	5.8	11.6	16.9	21.6	26.2	30.9
13	2.9	5.9	11.6	16.8	21.5	26.2	30.8
14	2.8	5.8	11.6	16.9	21.7	26.3	30.8
15	2.9	5.8	11.6	16.8	21.5	26.2	30.9
16	2.9	5.8	11.6	16.9	21.6	26.2	30.8
17	2.9	5.9	11.7	16.9	21.6	26.3	30.9
18	2.7	5.7	11.5	16.8	21.5	26.2	30.8
19	2.8	5.8	11.5	16.7	21.6	26.3	30.8
20	2.8	5.8	11.6	16.9	21.6	26.3	30.8
Sum	56.6	116.0	231.3	336.3	431.3	524.5	616.3
Average	2.83	5.8	11.565	16.815	21.565	26.225	30.815
SD	0.07	0.06	0.06	0.06	0.07	0.06	0.05

Replicate-3

Table 5.65: 4000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 Hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.9	9.4	14.5	19.0	23.5	27.8
2	2.5	5.0	9.5	14.5	19.0	23.5	27.7
3	2.3	4.8	9.4	14.5	19.1	23.6	27.8
4	2.5	5.0	9.5	14.5	19.1	23.6	27.9
5	2.5	4.9	9.4	14.4	19.0	23.6	27.8
6	2.5	4.9	9.5	14.6	19.2	23.7	27.9
7	2.5	4.9	9.4	14.5	19.1	23.6	27.9
8	2.5	5.0	9.5	14.6	19.1	23.5	27.8
9	2.4	4.8	9.4	14.5	19.1	23.7	27.9
10	2.3	4.8	9.4	14.5	19.1	23.6	27.9
11	2.4	4.9	9.5	14.5	19.1	23.7	27.9
12	2.4	4.8	9.4	14.5	19.0	23.5	27.7
13	2.5	4.9	9.4	14.5	19.1	23.6	27.8
14	2.4	4.9	9.4	14.4	19.0	23.5	27.7
15	2.5	5.0	9.5	14.6	19.2	23.7	27.9
16	2.3	4.8	9.4	14.5	19.1	23.6	27.8
17	2.5	4.9	9.5	14.6	19.2	23.7	27.9
18	2.4	4.9	9.5	14.6	19.2	23.7	27.9
19	2.4	4.8	9.4	14.5	19.0	23.6	27.9
20	2.4	4.9	9.4	14.4	19.0	23.5	27.8
Sum	48.6	97.8	188.8	290.2	381.7	472	556.7
Average	2.43	4.89	9.44	14.51	19.085	23.6	27.835
SD	0.07	0.07	0.04	0.06	0.07	0.07	0.07

Replicate-3

Table 5.66: 4500 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 4500 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.7	9.0	14.1	18.3	22.4	26.4
2	2.3	4.6	9.0	14.0	18.2	22.3	26.3
3	2.4	4.8	9.2	14.2	18.3	22.3	26.2
4	2.3	4.7	9.1	14.2	18.4	22.4	26.4
5	2.4	4.7	9.0	14.0	18.2	22.3	26.4
6	2.3	4.7	9.1	14.2	18.4	22.4	26.4
7	2.3	4.7	9.1	14.0	18.2	22.2	26.3
8	2.4	4.8	9.2	14.2	18.4	22.4	26.3
9	2.3	4.7	9.1	14.2	18.4	22.3	26.4
10	2.3	4.6	9.0	14.0	18.2	22.2	26.3
11	2.4	4.7	9.1	14.2	18.4	22.4	26.4
12	2.4	4.7	9.0	14.1	18.2	22.2	26.3
13	2.3	4.7	9.1	14.1	18.3	22.3	26.4
14	2.4	4.8	9.1	14.2	18.4	22.4	26.4
15	2.4	4.7	9.1	14.1	18.2	22.3	26.3
16	2.3	4.7	9.0	14.2	18.3	22.3	26.3
17	2.2	4.6	9.0	14.1	18.3	22.3	26.3
18	2.3	4.6	9.1	14.2	18.3	22.4	26.4
19	2.3	4.7	9.1	14.1	18.3	22.3	26.4
20	2.3	4.6	9.0	14.0	18.2	22.4	26.4
Sum	46.6	93.8	181.4	282.4	365.9	446.5	527.0
Average	2.33	4.69	9.07	14.12	18.295	22.325	26.35
SD	0.05	0.06	0.06	0.08	0.08	0.06	0.05

Replicate-3

Table 5.67: 5000 Hz sound treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Treatment – 5000 Hz							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.1	4.1	7.8	12.5	16.3	20.3	24.3
2	2.1	4.0	7.7	12.4	16.2	20.3	24.3
3	2.2	4.2	7.8	12.5	16.2	20.3	24.4
4	2.1	4.0	7.7	12.4	16.1	20.2	24.2
5	2.1	4.0	7.7	12.5	16.2	20.3	24.5
6	2.2	4.1	7.8	12.5	16.3	20.4	24.3
7	2.2	4.1	7.7	12.4	16.1	20.2	24.3
8	2.2	4.1	7.8	12.6	16.3	20.3	24.3
9	2.1	4.0	7.7	12.5	16.2	20.3	24.3
10	2.2	4.1	7.7	12.5	16.2	20.2	24.3
11	2.2	4.0	7.7	12.5	16.3	20.4	24.4
12	2.2	4.1	7.8	12.5	16.3	20.3	24.3
13	2.2	4.1	7.7	12.4	16.2	20.3	24.4
14	2.1	4.0	7.7	12.4	16.2	20.3	24.3
15	2.2	4.1	7.8	12.5	16.2	20.3	24.3
16	2.2	4.2	7.8	12.5	16.3	20.4	24.3
17	2.2	4.0	7.7	12.5	16.2	20.3	24.3
18	2.2	4.1	7.8	12.6	16.3	20.3	24.4
19	2.2	4.1	7.8	12.6	16.3	20.4	24.3
20	2.2	4.1	7.7	12.5	16.2	20.3	24.3
Sum	43.4	81.5	154.9	249.8	324.6	406.1	486.5
Average	2.17	4.075	7.745	12.49	16.23	20.305	24..325
SD	0.04	0.06	0.04	0.06	0.06	0.05	0.06

Table 5.68 depicts average plant growth of control and ten distinct frequency treated *Cicer arietinum* plants measured after 48, 96, 144, 192, 240, 288, and 336 hours. Figure 5.7 is the graphical representation of the Table 5.68. It is clear from the figure that all the audible frequency stimulated plants exhibited higher growth

Table 5.68: Control and ten different audible frequency stimulated *Cicer arietinum* plant growth averaged over of all the replicates

	48 hours	**96 hours**	**144 hours**	**192 hours**	**240 hours**	**288 hours**	**336 hours**
Control	2.21±0.07	4.19±0.07	8.07±0.12	12.98±0.11	17.00±0.11	21.16±0.09	25.24±0.07
500 Hz	2.27±0.05	4.31±0.07	8.29±0.07	13.26±0.08	17.24±0.10	21.33±0.06	25.52±0.07
1000 Hz	2.43±0.06	4.79±0.07	9.56±0.07	14.79±0.06	19.1±0.07	23.61±0.07	27.95±0.07
1500 Hz	2.73±0.06	5.49±0.08	10.74±0.08	15.81±0.09	20.49±0.08	25.01±0.09	29.51±0.08
2000 Hz	3.04±0.05	6.07±0.06	12.13±0.09	17.49±0.08	22.27±0.10	27.13±0.09	31.99±0.09
2500 Hz	3.34±0.05	6.75±0.07	13.63±0.06	19.41±0.07	24.41±0.07	29.41±0.07	34.42±0.07
3000 Hz	3.14±0.05	6.35±0.05	12.54±0.06	17.85±0.05	22.79±0.06	27.82±0.07	32.83±0.06
3500 Hz	2.85±0.06	5.82±0.06	11.57±0.06	16.78±0.07	21.53±0.08	26.21±0.07	30.78±0.07
4000 Hz	2.45±0.06	4.90±0.07	9.45±0.05	14.52±0.06	19.08±0.07	23.59±0.07	27.84±0.07
4500 Hz	2.34±0.05	4.69±0.07	9.09±0.07	14.13±0.08	18.31±0.08	22.35±0.07	26.37±0.06
5000 Hz	2.16±0.05	4.07±0.07	7.79±0.07	12.55±0.08	16.33±0.10	20.36±0.08	24.34±0.07

in terms of stem length from the beginning to the end of the experiment over the control plants except 5000 Hz. The best result was obtained at 2500 Hz frequency stimulation. Figure 5.8 depicts the average plant growth differences (in %) of ten different sound wave treated gram plants relative to control plants measured after above mentioned specified time intervals. At the end of the experiment, 1.1%, 10.7%, 16.9%, 26.7%, 36.3%, 30.0%, 21.9%, 10.3%, 4.4% increased and 3.5% decreased growth was noticed at 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, 4500 Hz, and 5000 Hz frequency stimulation respectively.

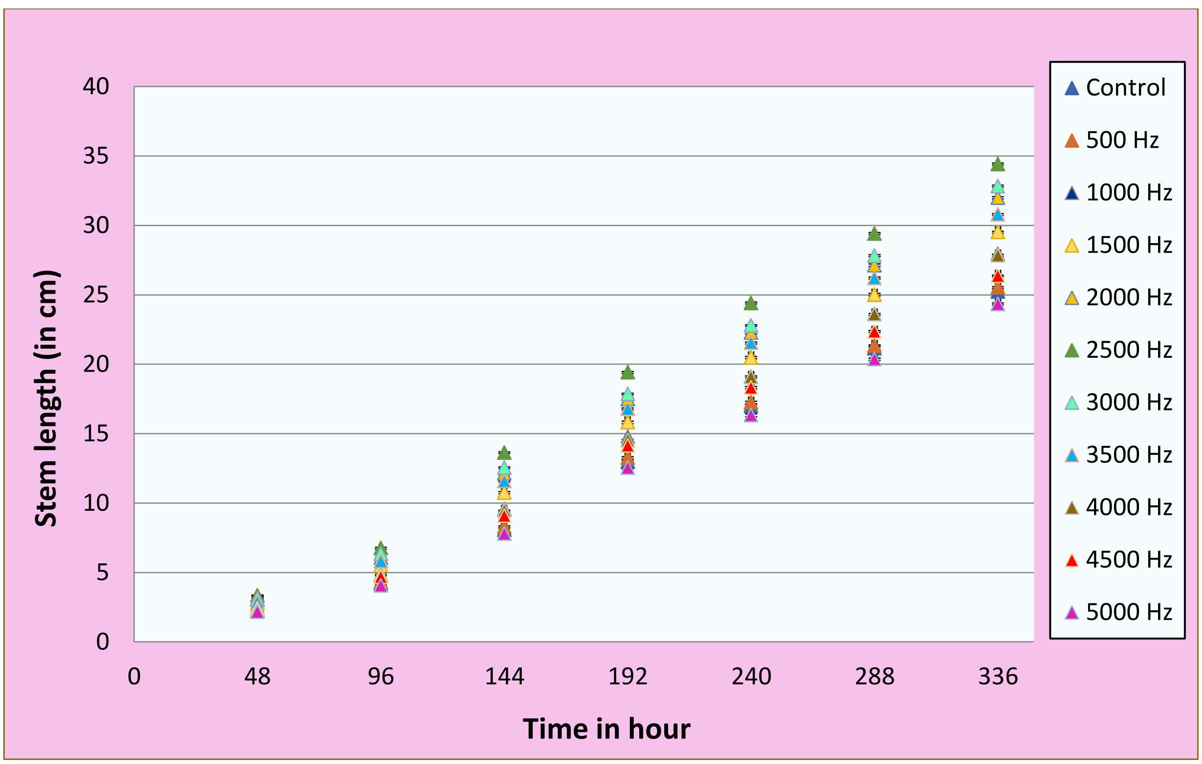


Fig.5.7: Graph showing average stem length of control and ten different audible frequency treated gram plants with time (Vertical bars represent mean ±SD)

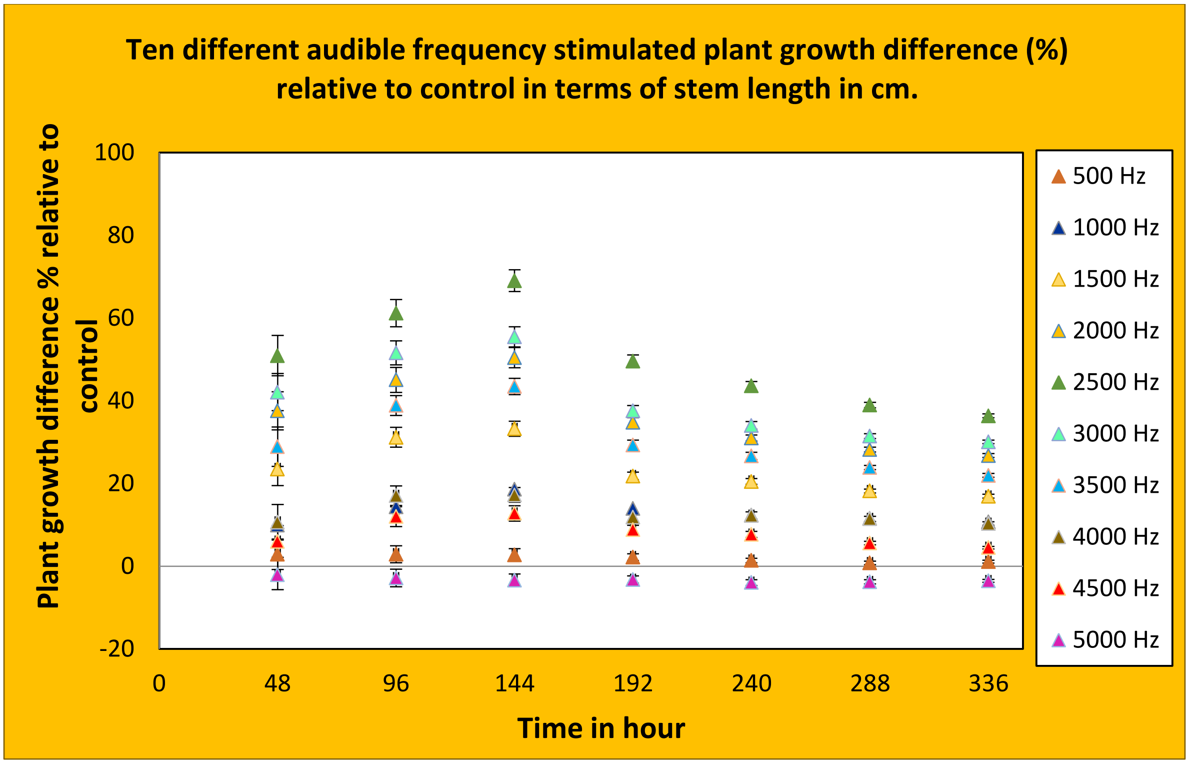


Fig.5.8: Graph showing comparative plant growth % of ten different audible frequency treated chickpea plants relative to control averaged over all the replicates (Vertical bars represent mean ±SD)

5.4 EVALUATION OF DATA

So, from the above findings it is evident that growth of both pea and gram plants were affected by audible sound wave of different frequencies. Significant differences have been found in growth parameter in terms of stem length at various frequency treatments after different time intervals.

In case of pea plants, the greatest growth in stem length were obtained at 2500 Hz frequency stimulation and the maximum growth percentage was achieved after 48 hour. 500 Hz, 1000 Hz, 1500 Hz, and 2000 Hz frequency treatments exhibited gradual lower to higher increased growth in pea plants when compared to control. But 3000 Hz, 3500 Hz, and 4000 Hz frequency treatments exhibited gradual higher to lower increased growth in pea plants than untreated control plants. The lowest positive growth rate was found at 4500 Hz frequency treatmentand the minimum growth rate percentage was found after 48 hour. Finally, at 5000 Hzfrequency treatment the pea plants exhibited negative growth rate percentage compared with that in the control plants. The plants of all the replicates revealed this species specific growth pattern with above mentioned varying frequency treatments after defined time intervals. These results implied that both lower as well as higher frequency treatments result in lower growth whereas intermediate frequency treatments manifested better growth results in pea plants.

Like pea plants, gram plants also exhibited highest growth in terms of stem length at 2500 Hz frequency stimulation when compared to control but the maximum positive growth percentage was perceived after 144 hour. On the other hand, plants generated lowest increased growth at 500 Hz frequency stimulation and the minimum positive growth rate percentage was found after 288 hour. This trend remains same for all the triplicates. Here, sound wave frequency from 500 Hz to 2500 Hz exhibited gradual improved plant growth in *Cicer arietinum* plant. But beyond 2500 Hz frequency treatments plant growth begins to decline and finally at 5000 Hz frequency treatment plants exhibited decreased growth than control.

As we have mentioned earlier any acoustic signal including music possesses two main features - pitch (frequency) and amplitude. The above results give only how the plant samples grow with frequency. However, this linear approach for studying growth of plants with frequency will not provide the real picture of variation of growth of plants with any sound system including music. As discussed earlier, we have quantified different music samples with the help of nonlinear parameter (DFA) for studying plant growth for music stimuli in chapter 7.

5.5 DISCUSSION

This study aimed to observe plant growth specially morphological changes to different audible sound wave frequencies. The results of the above two experiments manifest that plants not only perceive acoustic sounds but also respond to sound signals of different frequencies through modified growth and development. These effects also depend on other properties of sound wave like intensity and duration. Significant increases in plant growth regarding stem length was noticed in both pea and gram plants at 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2500 Hz, 3000 Hz, 3500 Hz, 4000 Hz, and 4500 Hz stimulation but negative growth was detected at 5000 Hz frequency stimulation when compared to untreated control plants. For both the plant species the best output was manifested at 2500 Hz frequency treatment but at different growth stages. Moreover, in both cases the highest frequency treatment (5000 Hz) brings down plant growth.

CHAPTER 6

QUANTITATIVE EFFECT OF MUSICAL SOUND ON SEED GERMINATION KINETICS IN *Pisum sativum* (pea) and *Cicer arietinum* (gram)

6.1 INTRODUCTION

Plant starts life cycle with a crucial step of seed germination. It is essential for emergence of seedling, producing viable offspring and ultimately rebuilding the productivity. Germination of seed is very complex phenomenon and controlled by different intrinsic and extrinsic factors. Sound is one kind of acoustics energy and affects germination in different plant species distinctly. Scientific evidences regarding the effects of sound waves on seed germination have already been discussed in review literature section (chapter 2) and it was seen that very little work has been done with audible sounds mainly how seed germination is affected by music. But these studies did not look at effect of musical sound from acoustical complexities point of view. Seed germination kinetics, particularly germination speed contributes a major role in the variability of germination. This study aimed to investigate the quantitative effect of musical sound with specific spectral characteristics mainly DFA scaling exponent on seed germination kinetics of *Pisum sativum* (pea) and *Cicer arietinum* (gram).

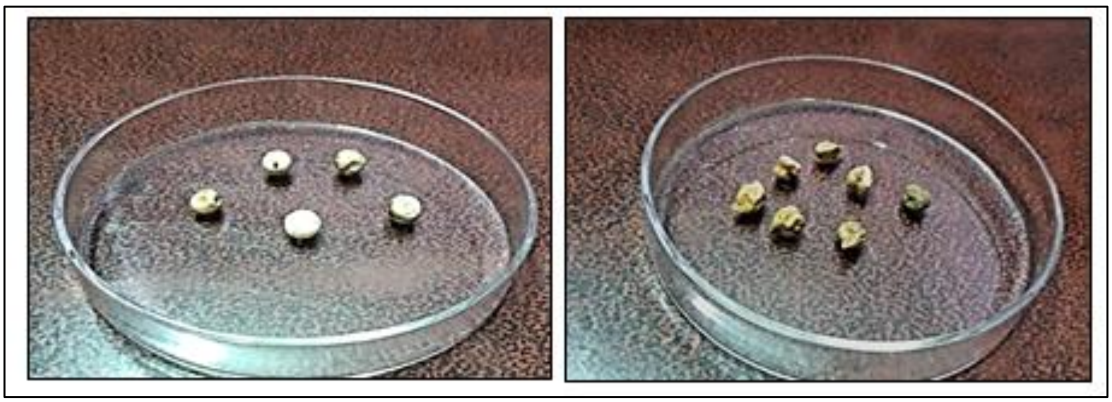
6.2 METHODOLOGY

6.2.1 DETRENDED FLUCTUATION ANALYSIS OF MUSIC SIGNALS

Here, Indian Classical music and Natural music was used as audio signals to stimulate *Pisum sativum* and *Cicer arietinum*s eeds. The DFA computation method has already discussed in chapter 3.

6.2.2 SEED MATERIALS

Pisum sativum and *Cicer arietinum* seeds (production place: Kolkata, India) with 12% moisture content were used for the experiment. These types of seeds were chosen due to their large size. At first the cracked, crushed, moldy and discoloured seeds were removed (Fig.6.1). The smallest as well as the largest seeds were also removed to maintain the uniformity of size. After that the sorted seeds of necessary number were counted individually and measured to the nearest mass for the experiments. As we cannot detect split or cracked seeds till the seeds soaked in water, an additional 15% seeds remain prepared for the experiments. Next, the seeds were rinsed in 1% bleach solution for 30 minutes for removing fungus and mold on the seeds. After that seeds were washed ten times in running water to remove residual disinfectant and speed up germination. Then the seeds were soaked in water for a long time and then placed in the petri dishes. Before use the petri dishes were also rinsed in bleach solution to reduce contamination. Then the petri dishes were labelled. The whole preparation was done separately for each of the seed type.



(A) (B)

Fig.6.1: Discarded seeds of (A) *Pisum sativum* (B) *Cicer arietinum*

6.2.3 EXPERIMENTAL DESIGN FOR MUSIC TREATMENT

To understand the effect of musical sound on seed germination, Indian Classical music and Natural music stimuli were used as audio signals to both *Pisum sativum* and *Cicer arietinum* seeds during the germination period. The study was based on randomised control design. Experiments were conducted in three groups:Indian

Classical music treatment group, Natural music treatment group, and control group. Each group included four symmetry cultivation units for each seed type and for every cultivation unit the numbers of seeds were 20. A total of 3 trials were run testing 720 *Pisum sativum*and 720 *Cicer arietinum* seeds. Identical growth chambers were used for each group. Each growth chamber had an identical speaker inside. Figure 6.2 shows the schematic diagram of single experimental growth chamber. The difference between conditions was whether the musical sound was on (treated) or off (control) and what musical sound was played through the speaker. Music was continuously played using music player and the player contin-

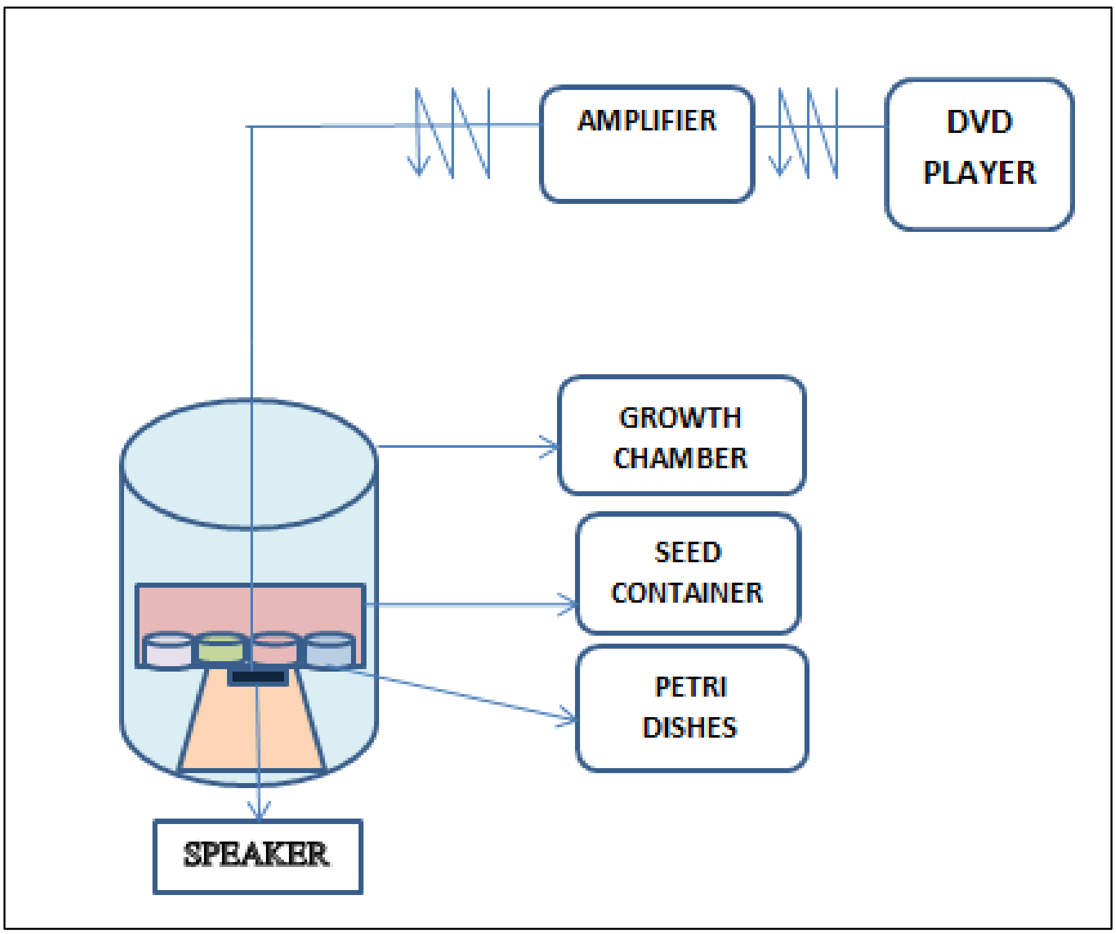


Fig.6.2: Schematic diagram of single experimental growth chamber showing 4 replicates

-uously replayed for a period of 72 hour through the speaker by adjusting the volume at 80 dB. The pieces of music and volume of the pieces remain constant throughout the whole experimental period. Watering was done for 2 minutes every one hour initially and then at each 6- hour interval in such a way that the seeds were neither over-watered nor under-watered. The environmental conditions of the test room (continuous dark condition, temperature 26 ± 2^{o}C, and humidity 66 ± 6%) remain same for all the treated and untreated set of seeds.

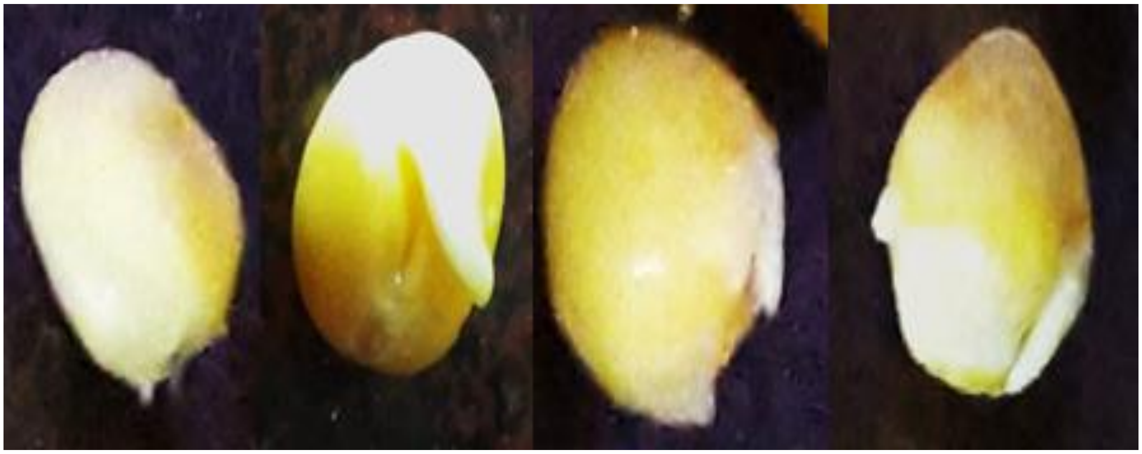
6.2.4 GERMINATION TEST

A seed is an embryo enclosed in a seed testa which contains necessary nutrients for sprouting. After imbibition in water seed swells and testa splits, this indicates seed germination. When the embryo axes protruded 2.0 mm, the seed was considered as a germinated seed. Here, germination was used as a quantitative measure. Figure 6.3 (A, B) is the photograph showing visual differences in early germination stages of *Pisum sativum* and *Cicer arietinum*s eed respectively. The number of sprouted seeds was counted every 12- hour intervals over 72 hour long runs. Throughout the whole experiment, seeds were also photographed in their petri dishes. Germination kinetics was evaluated in terms of Germination Percentage and Mean Germination Time. Germination percentage indicates the viability and potential of a seed. Mean germination time is an index for germination speed. The Germination Percentage and Mean germination time were calculated as follows:

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100 \quad \text{................(1)}$$

$$\text{Mean Germination Time} = \frac{\sum (nt)}{\sum N} \quad \text{..(2)}$$

where n is the number of newly germinated seeds at time t, t is the germination time of newly germinated seeds, and N is the total number of germinated seeds.



(A)

(B)

Fig.6.3: Visual differences in early germination stages of (A) *Pisum sativum* seed and (B) *Cicer arietinum* seed

6.3 RESULTS

6.3.1 DFA SCALING EXPONENTS OF MUSIC SIGNALS

As discussed earlier that each music has a specific spectral characteristics and pattern of self-similarity with a distinctive DFA scaling exponent (α), which is actually the originality of that music in turns of acoustical complexity.DFA was applied on the extracted amplitude envelopes on a moving window basis with a window size of 60s taking an overlap of 50% between the windows. A single scaling exponent α was obtained corresponding to each window of 60 seconds.

Table 6.1 shows the variation of DFA Scaling Exponents for the two different musical stimuli-Indian Classical music and Natural music used in our study.The values indicate that Indian Classical Music had higher long-range temporal correlation (LRTC) compared to Natural Music. This variation in the scaling pattern is responsible for distinct responsiveness in living organisms.

Table 6.1: Variation of DFA scaling exponent for different parts of 4 musical stimuli

	DFA scaling exponent	
	Clip 1 IndianClassical music	**Clip 2 Natural music**
Part 1	1.652	1.277
Part 2	1.584	1.489
Part 3	1.815	1.398

6.3.2 ANALYSIS OF SEED GERMINATION KINETICS

6.3.2.1 ANALYSIS OF SEED GERMINATION KINETICS IN *Pisum sativum*

The *Pisum sativum* seeds started germination after 12 hours irrespective of both music treatments. The number of sprouted seeds for Indian Classical music treated seed groups, Natural music treated seed groups and untreated control seed groups were measured from the beginning to every 12- hour intervals over 72 hour long runs and Table 6.2, Table 6.3, and Table 6.4 shows the above mentioned group data for trial-1,trial- 2, and trial -3 respectively. Figure 6.4 shows the photographs of control and two different musical sound treated *Pisum sativum* seeds sprout throughout the elapsed time (trial 2, Replicate 1). Table 6.5 depicts the total number of *Pisum sativum* sprouted seeds at different time intervals for the three

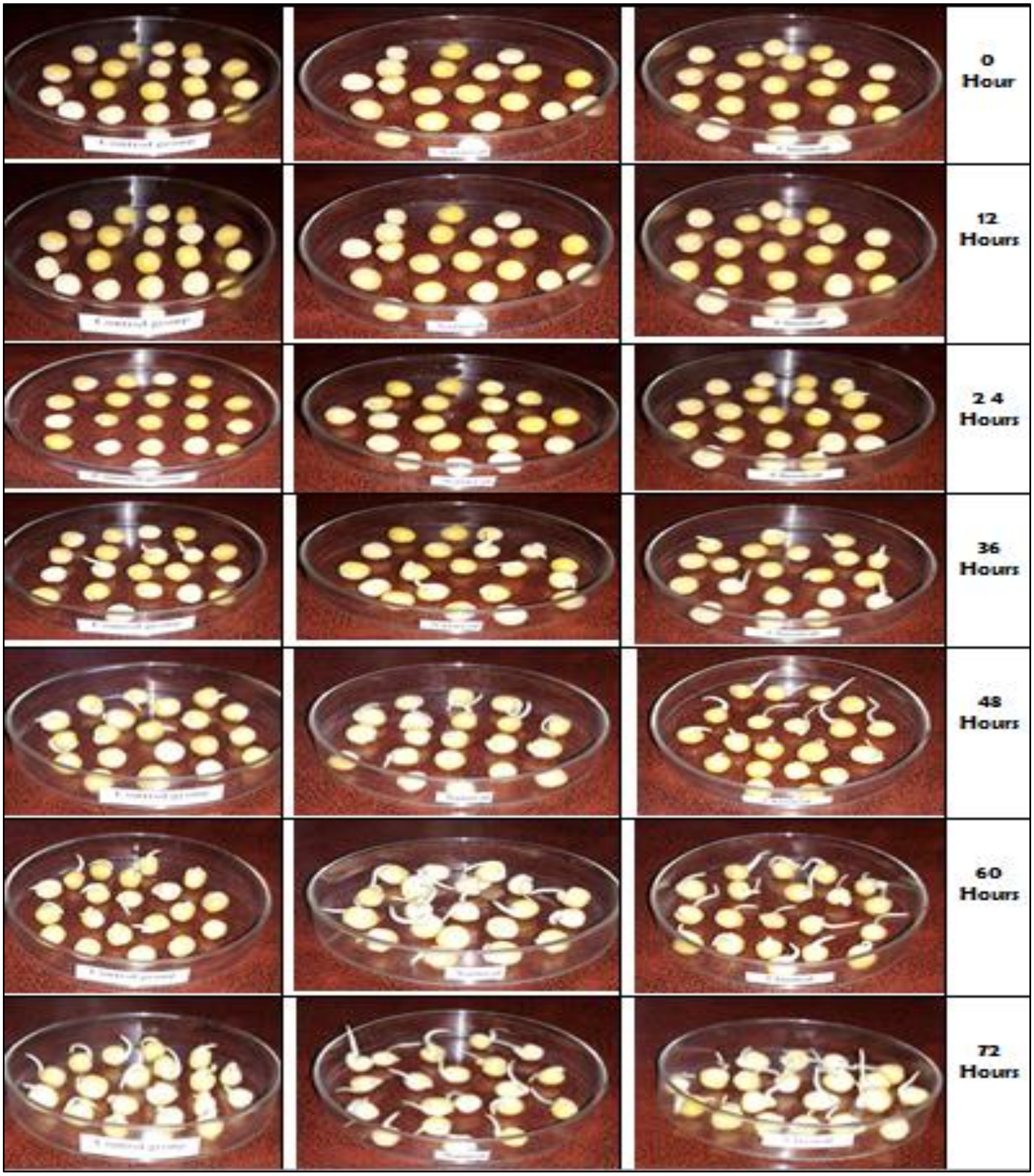


Fig.6.4: Photographs of control and two different musical sounds treated *Pisum sativum* seeds sprout at 0, 12, 24, 36, 48, 60, and 72 hours (trial 2, Replicate 1)

experimental conditions taking replicates of all the trials. Table 6.6 presents the percentage of sprouted seeds for both of the music treated seed groups and relative control groups averaged over replicates of all the trials. Figure 6.5 is the graphical representation of Table 6.6. Mean Germination Time (MGT) was also determined for the Indian Classical music treated seed groups, Natural music treated seed groups and relative control seed groups and Table 6.7, Table 6.8, and Table 6.9 represents the MGT for trial-1, trial 2, and trial 3 respectively. Table 6.10 depicting the MGT of control and music treated seed groups averaged over replicates of all the trials and Figure 6.6 has drawn from this table to make the data more presentable.

Table 6.2: Number of *Pisum sativum* sprouted seeds at different time intervals for the three experimental conditions, Trial-1

TRIAL-1								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	Replicate 1	0	0	3	5	9	13	18
	Replicate 2	0	0	2	5	9	13	17
	Replicate 3	0	0	3	5	8	12	17
	Replicate 4	0	0	2	5	8	13	17
Indian Classical music treatment	Replicate 1	0	0	6	10	14	20	20
	Replicate 2	0	0	6	9	14	20	20
	Replicate 3	0	0	5	9	14	20	20
	Replicate 4	0	0	6	9	14	20	20
Natural music treatment	Replicate 1	0	0	5	8	13	19	20
	Replicate 2	0	0	5	8	13	19	20
	Replicate 3	0	0	5	8	13	19	20
	Replicate 4	0	0	5	8	13	18	20

Table 6.3: Number of *Pisum sativum* sprouted seeds at different time intervals for the three experimental conditions, Trial-2

TRIAL-2								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	Replicate 1	0	0	3	6	9	13	18
	Replicate 2	0	0	3	5	8	13	17
	Replicate 3	0	0	3	5	8	13	18
	Replicate 4	0	0	2	5	8	12	17
Indian Classical music treatment	Replicate 1	0	0	6	10	14	20	20
	Replicate 2	0	0	6	9	14	20	20
	Replicate 3	0	0	6	9	14	20	20
	Replicate 4	0	0	6	9	14	20	20
Natural music treatment	Replicate 1	0	0	5	8	12	18	20
	Replicate 2	0	0	5	8	13	18	20
	Replicate 3	0	0	5	8	13	19	20
	Replicate 4	0	0	5	8	13	18	20

Table 6.4: Number of *Pisum sativum* sprouted seeds at different time intervals for the three experimental conditions, Trial-3

TRIAL-3								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	Replicate 1	0	0	2	5	9	13	18
	Replicate 2	0	0	3	5	8	12	17
	Replicate 3	0	0	3	6	9	13	18
	Replicate 4	0	0	2	5	8	13	17
Indian Classical music treatment	Replicate 1	0	0	5	9	14	20	20
	Replicate 2	0	0	6	10	15	20	20
	Replicate 3	0	0	6	9	14	20	20
	Replicate 4	0	0	6	9	14	20	20
Natural music treatment	Replicate 1	0	0	5	8	13	19	20
	Replicate 2	0	0	5	8	12	18	20
	Replicate 3	0	0	5	8	13	19	20
	Replicate 4	0	0	5	8	13	19	20

Table 6.5: Total number of *Pisum sativum* sprouted seeds at different time intervals for the three experimental conditions taking replicates of all the trials together

Experimental groups	Number of sprouted seeds out of 240						
	0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	0	0	31	62	101	153	209
Indian Classical music treatment	0	0	70	111	169	240	240
Natural music treatment	0	0	60	96	154	223	240

Table 6.6:Percentage of *Pisum sativum* sprouted seeds in elapsed time for three experimental conditions averaged over replicates of all the trials

Experimental groups	Percentage of sprouted seeds						
	0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	0	0	12.91	25.83	42.08	63.75	87.08
Indian Classical music treatment	0	0	29.16	46.25	70.41	100	100
Natural music treatment	0	0	25	40	64.16	92.91	100

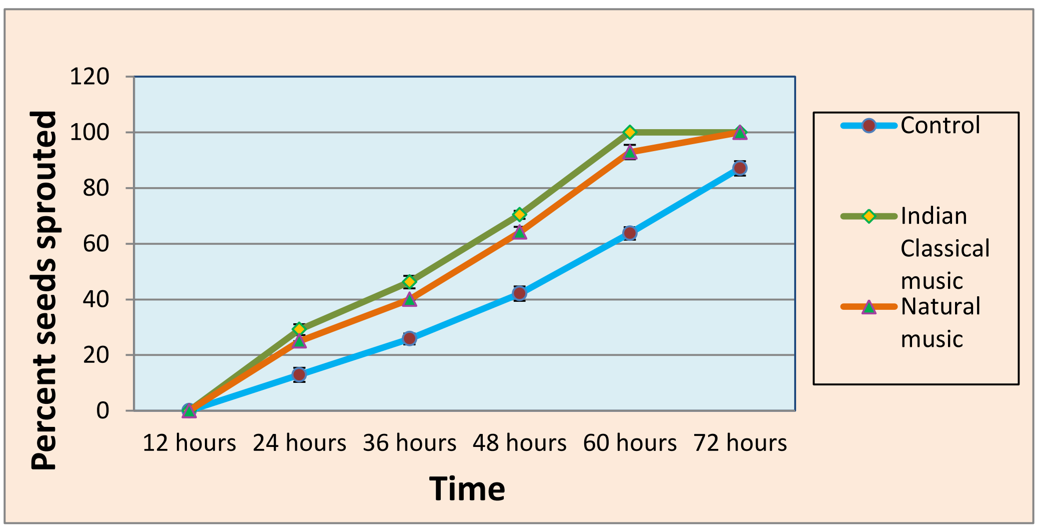


Fig 6.5: Percentage of *Pisum sativum* sprouted seeds for both the musictreated and control seed groups versus time averaged over replicates of all the trials (Vertical bars represent mean ±SD)

Table 6.7: Mean Germination Time (MGT) of *Pisum sativum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-1

TRIAL-1

Experimental		0 Hr		12 Hrs		24 Hrs		36 Hrs		48 Hrs		60 Hrs		72 Hrs				
groups	Replications	n	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	∑n	∑nt	MGT (Hr.)
	Replicate 1	0	0	0	0	3	72	2	72	4	192	4	240	5	360	18	936	52
	Replicate 2	0	0	0	0	2	48	3	108	4	192	4	240	4	288	17	876	51.52
Control	Replicate 3	0	0	0	0	3	72	2	72	3	144	4	240	5	360	17	888	52.23
	Replicate 4	0	0	0	0	2	48	3	108	3	144	5	300	4	288	17	888	52.23
	Replicate 1	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
Indian Classical	Replicate 2	0	0	0	0	6	144	4	144	4	192	6	360	0	0	20	840	42
music treatment	Replicate 3	0	0	0	0	5	120	4	144	5	240	6	360	0	0	20	864	43.2
	Replicate 4	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
	Replicate 1	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
Natural music treatment	Replicate 2	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
	Replicate 3	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
	Replicate 4	0	0	0	0	5	120	3	108	5	240	5	300	2	144	20	912	45.6

Table 6.8: Mean Germination Time (MGT) of *Pisum sativum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-2.

TRIAL-2																		
Experimental Groups	Replications	0 Hr		12 Hrs		24 Hrs		36 Hrs		48 Hrs		60 Hrs		72 Hrs				MGT (Hr.)
		n	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	∑n	∑nt	
Control	Replicate 1	0	0	0	0	3	72	3	108	3	144	4	240	5	360	18	924	51.33
	Replicate 2	0	0	0	0	3	72	2	72	3	144	5	300	4	288	17	876	51.52
	Replicate 3	0	0	0	0	3	72	2	72	3	144	5	300	5	360	18	948	52.66
	Replicate 4	0	0	0	0	2	48	3	108	3	144	4	240	5	360	17	900	52.94
Indian Classical music treatment	Replicate 1	0	0	0	0	6	144	4	144	4	192	6	360	0	0	20	840	42
	Replicate 2	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
	Replicate 3	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
	Replicate 4	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
Natural music Treatment	Replicate 1	0	0	0	0	5	120	3	108	4	192	6	360	2	144	20	924	46.2
	Replicate 2	0	0	0	0	5	120	3	108	5	240	5	300	2	144	20	912	45.6
	Replicate 3	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
	Replicate 4	0	0	0	0	5	120	3	108	5	240	5	300	2	144	20	912	45.6

Table 6.9: Mean Germination Time (MGT) of *Pisum sativum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-3

TRIAL-3																			
Experimental groups	Replications	0 Hr		12 Hrs		24 Hrs		36 Hrs		48 Hrs		60 Hrs		72 Hrs					
		n	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	N	nXt	∑n	∑nt	MGT (Hr.)
Control	Replicate 1	0	0	0	0	2	48	3	108	4	192	4	240	5	360	18	948	52.66
	Replicate 2	0	0	0	0	3	72	2	72	3	144	4	240	5	360	17	888	52.23
	Replicate 3	0	0	0	0	3	72	3	108	3	144	4	240	5	360	18	924	51.33
	Replicate 4	0	0	0	0	2	48	3	108	3	144	5	300	4	288	17	888	52.23
Indian Classical music treatment	Replicate 1	0	0	0	0	5	120	4	144	5	240	6	360	0	0	20	864	43.2
	Replicate 2	0	0	0	0	6	144	4	144	5	240	5	300	0	0	20	828	41.4
	Replicate 3	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
	Replicate 4	0	0	0	0	6	144	3	108	5	240	6	360	0	0	20	852	42.6
Natural music treatment	Replicate 1	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
	Replicate 2	0	0	0	0	5	120	3	108	4	192	6	360	2	144	20	924	46.2
	Replicate 3	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45
	Replicate 4	0	0	0	0	5	120	3	108	5	240	6	360	1	72	20	900	45

Table 6.10: Mean Germination Time (MGT) of *Pisum sativum* sprouted seeds for control, Indian Classical music, and Natural music treatments averaged over replicates of all the trials

Experimental groups	MGT (Hr.)
Control	52.07±0.54
Indian Classical music treatment	42.5±0.5
Natural music treatment	45.3±0.47

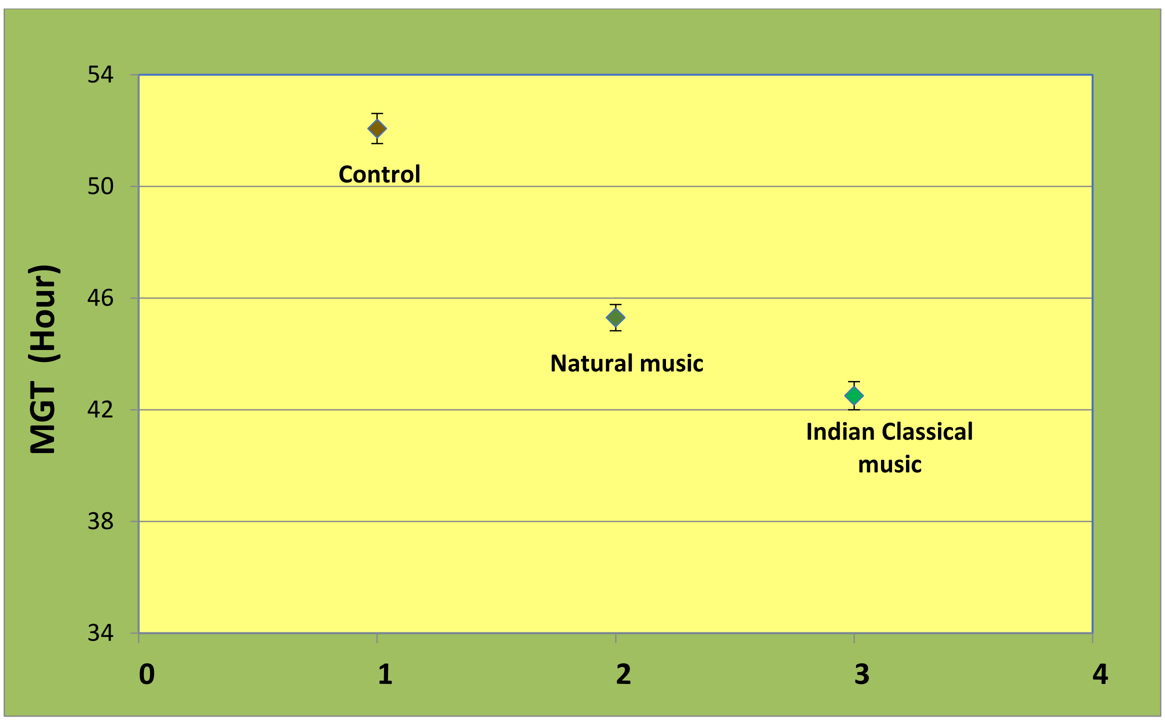


Fig 6.6: Mean germination time (MGT) of control and two types of music treated *Pisum sativum* seed groups averaged over replicates of all the trials (Vertical bars represent mean ± SD)

The above results clearly demonstrate that for all the three trials, seeds exposed to musical sound sprouted rapidly than untreated control. Significant differences have been observed in percentage of sprouted seeds and Mean germination Time (MGT) among the three different experimental seed groups. Indian Classical music treated groups exhibited greatest percentage of sprouted seeds followed by Natural music treated seed groups and untreated control groups throughout the elapsed time. For all the trials, Indian Classical music treated groups showed 100 percent sprouted seeds after 60 hours; while the Natural music treated groups exhibited 100 percent sprouted seeds after 72 hours. But at the end of the experiment, untreated control groups showed 87.08 % sprouted seeds when averaged over replicates of all trials. The music treated seed groups exhibited reduced t50, the time taken to reach 50% of total seed germination when compared to the untreated control seed groups. Indian Classical Music treated seeds germinated with a lowest MGT of 42.5 hours, Natural Music treated seeds showed 45.3 hours of MGT and the untreated control group germinated with highest MGT of 52.07 hours when averaged over replicates of three trials.

6.3.2.2 ANALYSIS OF SEED GERMINATION KINETICS IN *Cicer arietinum*

The *Cicer arietinum* seeds started germination after 24 hours irrespective of all treatments in all experimental trials. The number of *Cicer arietinum* sprouted seeds for Indian Classical music treated groups, Natural music treated groups and untreated control groups were measured from the beginning to the end of the experiment over 72 hour long runs at every 12- hour intervals. Figure 6.7 shows the photographs of control and two different musical sound treated *Cicer arietinum* seeds sprout at every 12- hour intervals throughout the experimental time period (trial 2, Replicate 1). Table 6.11, Table 6.12, and Table 6.13 shows the number of

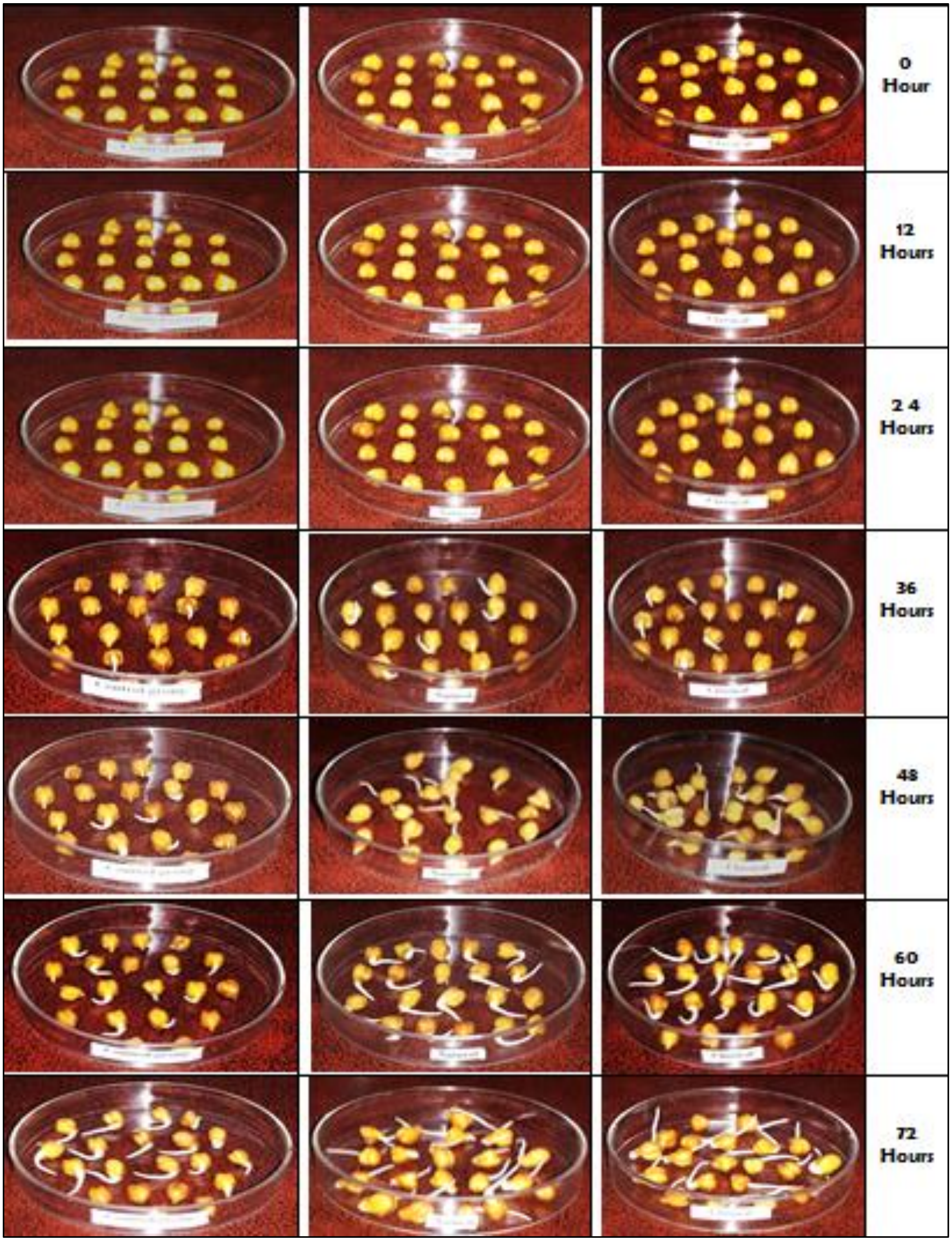


Fig.6.7: Photographs of control and two different musical sounds treated *Cicer arietinum* seeds sprout at 0, 12, 24, 36, 48, 60, and 72 hours (trial 2, Replicate 1)

sprouted seeds of Indian Classical music treated, Natural music treated and untreated control groups for trial-1, trial- 2, and trial -3 respectively. Table 6.14 depicts the total number of *Cicer arietinum* sprouted seeds at different time intervals for the three experimental conditions taking replicates of all the trials. Table 6.15 shows the percentage of sprouted seeds for both of the music treated groups and relative control seed groups averaged over replicates of all the three trials. Figure 6.8 graphically representing the table 6.15. Mean Germination Time (MGT) was also calculated for the Indian Classical music treated groups, Natural music treated groups, and relative control groups. Table 6.16, Table 6.17, Table 6.18 shows the MGT data for trial-1, trial 2, and trial 3 respectively and Table 6.19 represents the average MGT of control and two music treated seed groups. Figure 6.9 has drawn from Table 6.19 to make the data more discernible.

Table 6.11: Number of *Cicer arietinum* sprouted seeds at different time intervals for the three experimental conditions, Trial-1

TRIAL-1								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
CONTROL	Replicate 1	0	0	0	3	6	10	15
	Replicate 2	0	0	0	3	7	11	16
	Replicate 3	0	0	0	3	6	10	15
	Replicate 4	0	0	0	3	6	10	15
INDIAN CLASSICAL MUSIC TREATMENT	Replicate 1	0	0	0	7	11	16	20
	Replicate 2	0	0	0	7	11	15	20
	Replicate 3	0	0	0	7	11	16	20
	Replicate 4	0	0	0	6	11	16	20
NATURAL MUSIC TREATMENT	Replicate 1	0	0	0	5	9	14	19
	Replicate 2	0	0	0	5	9	14	18
	Replicate 3	0	0	0	5	9	13	18
	Replicate 4	0	0	0	4	8	13	18

Table 6.12: Number of *Cicer arietinum* sprouted seeds at different time intervals for the three experimental conditions, Trial-2

TRIAL-2								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
CONTROL	Replicate 1	0	0	0	3	6	10	15
	Replicate 2	0	0	0	3	7	11	16
	Replicate 3	0	0	0	3	7	11	16
	Replicate 4	0	0	0	2	6	11	16
INDIAN CLASSICAL MUSIC TREATMENT	Replicate 1	0	0	0	7	12	16	20
	Replicate 2	0	0	0	6	11	16	20
	Replicate 3	0	0	0	6	11	16	20
	Replicate 4	0	0	0	6	10	15	20
NATURAL MUSIC TREATMENT	Replicate 1	0	0	0	5	9	13	18
	Replicate 2	0	0	0	5	9	13	18
	Replicate 3	0	0	0	6	10	14	19
	Replicate 4	0	0	0	5	9	13	18

Table 6.13: Number of *Cicer arietinum* sprouted seeds at different time intervals for the three experimental conditions, Trial-3

TRIAL-3								
Experimental groups	Replications	Number of sprouted seeds out of 20						
		0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
CONTROL	Replicate 1	0	0	0	3	7	11	16
	Replicate 2	0	0	0	3	6	10	15
	Replicate 3	0	0	0	3	7	11	15
	Replicate 4	0	0	0	2	6	10	15
INDIAN CLASSICAL MUSIC TREATMENT	Replicate 1	0	0	0	6	10	15	20
	Replicate 2	0	0	0	6	10	16	20
	Replicate 3	0	0	0	6	10	15	20
	Replicate 4	0	0	0	7	11	16	20
NATURAL MUSIC TREATMENT	Replicate 1	0	0	0	5	10	15	19
	Replicate 2	0	0	0	4	9	13	18
	Replicate 3	0	0	0	5	9	13	18
	Replicate 4	0	0	0	4	8	13	17

Table 6.14: Total number of *Cicer arietinum* sprouted seeds at different time intervals for the three experimental conditions taking replicates of all the trials together

Experimental groups	Number of sprouted seeds out of 240						
	0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	0	0	0	34	77	126	185
Indian Classical music treatment	0	0	0	77	129	188	240
Natural music treatment	0	0	0	58	108	161	218

Table 6.15: Percentage of sprouted *Cicer arietinum* seeds in elapsed time for three experimental conditions averaged over replicates of all the trials

Experimental groups	Percentage of sprouted seeds						
	0 Hr.	12 Hrs.	24 Hrs.	36 Hrs.	48 Hrs.	60 Hrs.	72 Hrs.
Control	0	0	0	14.16	32.08	52.5	77.08
Indian Classical music treatment	0	0	0	32.08	53.75	78.33	100
Natural music treatment	0	0	0	24.16	45	67.08	90.8

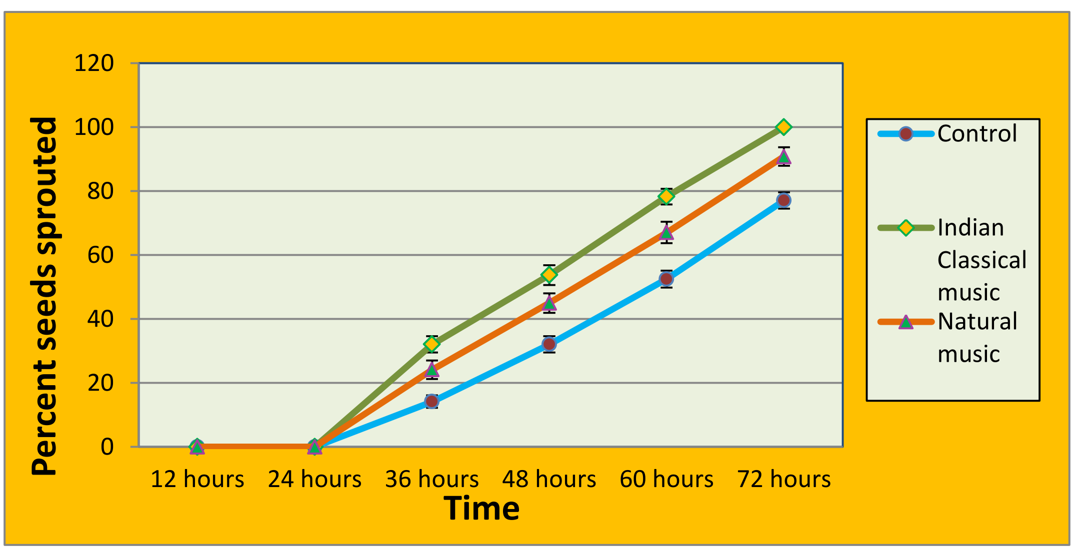


Fig. 6.8: Percentage of *Cicer arietinum* sprouted seeds for both the music treated and control seed groups versus time averaged over replicates of all the trials (Vertical bars represent mean ±SD)

Table 6.16: Mean Germination Time (MGT) of *Cicer arietinum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-1

TRIAL-1																			
Experimental groups	Replications	0 Hr.		12 Hrs.		24 Hrs.		36 Hrs.		48 Hrs.		60 Hrs.		72 Hrs.					MGT (Hr.)
		n	nXt	N	nXt	n	nXt	N	nXt	N	nXt	n	nXt	N	nXt	∑n	∑nt		
control	Replicate 1	0	0	0	0	0	0	3	108	3	144	4	240	5	360	15	852		56.8
	Replicate 2	0	0	0	0	0	0	3	108	4	192	4	240	5	360	16	900		56.25
	Replicate 3	0	0	0	0	0	0	3	108	3	144	4	240	5	360	15	852		56.8
	Replicate 4	0	0	0	0	0	0	3	108	3	144	4	240	5	360	15	852		56.8
Indian Classical music treatment	Replicate 1	0	0	0	0	0	0	7	252	4	192	5	300	4	288	20	1032		51.6
	Replicate 2	0	0	0	0	0	0	7	252	4	192	4	240	5	360	20	1044		52.2
	Replicate 3	0	0	0	0	0	0	7	252	4	192	5	300	4	288	20	1032		51.6
	Replicate 4	0	0	0	0	0	0	6	216	5	240	5	300	4	288	20	1044		52.2
Natural music treatment	Replicate 1	0	0	0	0	0	0	5	180	4	192	5	300	5	360	19	1032		54.31
	Replicate 2	0	0	0	0	0	0	5	180	4	192	5	300	4	288	18	960		53.33
	Replicate 3	0	0	0	0	0	0	5	180	4	192	4	240	5	360	18	972		54
	Replicate 4	0	0	0	0	0	0	4	144	4	192	5	300	5	360	18	996		55.33

Table 6.17: Mean Germination Time (MGT) of *Cicer arietinum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-2

TRIAL-2																		
Experimental groups	Replications	0 Hr.		12 Hrs.		24 Hrs.		36 Hrs.		48 Hrs.		60 Hrs.		72 Hrs.		∑n	∑nt	MGT (Hr.)
		n	nXt	N	nXt	n	nXt	N	nXt	N	nXt	n	nXt	N	nXt			
control	Replicate 1	0	0	0	0	0	0	3	108	3	144	4	240	5	360	15	852	56.8
	Replicate 2	0	0	0	0	0	0	3	108	4	192	4	240	5	360	16	900	56.25
	Replicate 3	0	0	0	0	0	0	3	108	4	192	4	240	5	360	16	900	56.25
	Replicate 4	0	0	0	0	0	0	2	72	4	192	5	300	5	360	16	924	57.75
Indian Classical music treatment	Replicate 1	0	0	0	0	0	0	7	252	5	240	4	240	4	288	20	1020	51
	Replicate 2	0	0	0	0	0	0	6	216	5	240	5	300	4	288	20	1044	52.2
	Replicate 3	0	0	0	0	0	0	6	216	5	240	5	300	4	288	20	1044	52.2
	Replicate 4	0	0	0	0	0	0	6	216	4	192	5	300	5	360	20	1068	53.4
Natural music treatment	Replicate 1	0	0	0	0	0	0	5	180	4	192	4	240	5	360	18	972	54
	Replicate 2	0	0	0	0	0	0	5	180	4	192	4	240	5	360	18	972	54
	Replicate 3	0	0	0	0	0	0	6	216	4	192	4	240	5	360	19	1008	53.05
	Replicate 4	0	0	0	0	0	0	5	180	4	192	4	240	5	360	18	972	54

Table 6.18: Mean Germination Time (MGT) of *Cicer arietinum* sprouted seeds for control, Indian Classical music, and Natural music treatments, Trial-3

TRIAL-3																			
Experimental		0 Hr.		12 Hrs.		24 Hrs.		36 Hrs.		48 Hrs.		60 Hrs.		72 Hrs.				MGT
groups	Replications	n	nXt	N	nXt	n	nXt	N	nXt	N	nXt	n	nXt	N	nXt	∑n	∑nt	(Hr.)
Control	Replicate 1	0	0	0	0	0	0	3	108	4	192	4	240	5	360	16	900	56.25
	Replicate 2	0	0	0	0	0	0	3	108	3	144	4	240	5	360	15	852	56.8
	Replicate 3	0	0	0	0	0	0	3	108	4	192	4	240	4	288	15	828	55.2
	Replicate 4	0	0	0	0	0	0	2	72	4	192	4	240	5	360	15	864	57.6
Indian Classical music treatment	Replicate 1	0	0	0	0	0	0	6	216	4	192	5	300	5	360	20	1068	53.4
	Replicate 2	0	0	0	0	0	0	6	216	4	192	6	360	4	288	20	1056	52.8
	Replicate 3	0	0	0	0	0	0	6	216	4	192	5	300	5	360	20	1068	53.4
	Replicate 4	0	0	0	0	0	0	7	252	4	192	5	300	4	288	20	1032	51.6
Natural music treatment	Replicate 1	0	0	0	0	0	0	5	180	5	240	5	300	4	288	19	1008	53.05
	Replicate 2	0	0	0	0	0	0	4	144	5	240	4	240	5	360	18	984	54.66
	Replicate 3	0	0	0	0	0	0	5	180	4	192	4	240	5	360	18	972	54
	Replicate 4	0	0	0	0	0	0	4	144	4	192	5	300	4	288	17	924	54.35

Table 6.19: Mean Germination Time (MGT) of *Cicer arietinum* sprouted seeds for control, Indian Classical music, and Natural music treatments averaged over replicates of all the trials

Experimental groups	Mean Germination Time (Hr.)
Control	56.6±0.67
Indian Classical music treatment	52.3±0.8
Natural music treatment	54±0.65

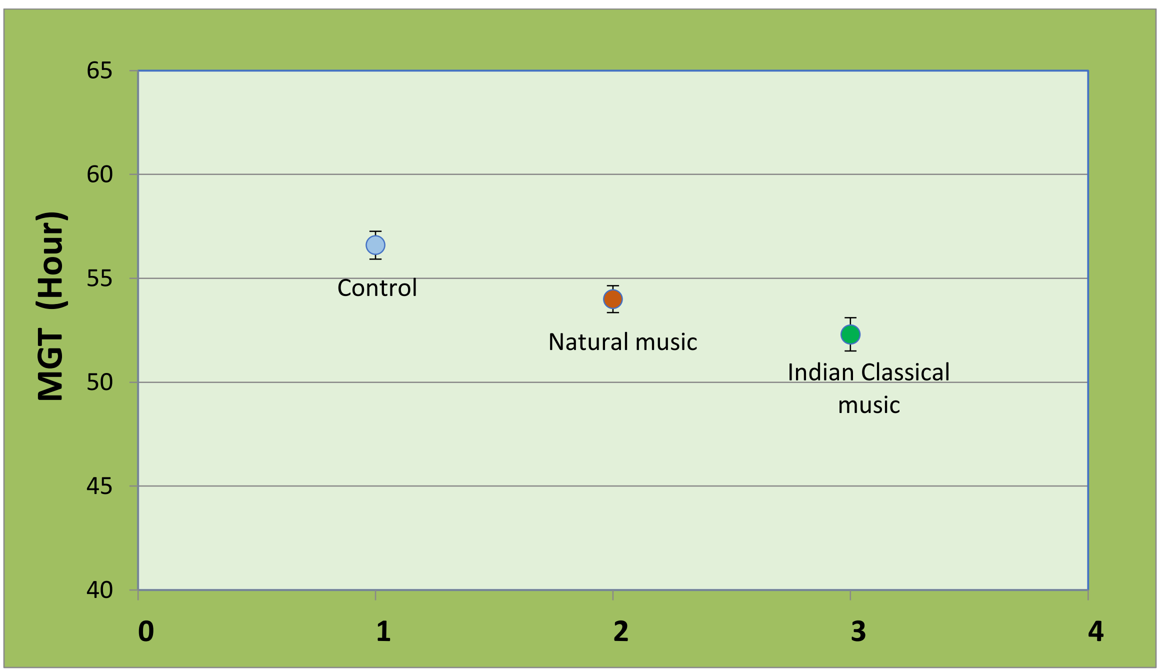


Fig. 6.9: Mean germination time (MGT) of control and two types of music treated *Cicer arietinum* seed groups averaged over replicates of all the trials (Vertical bars represent mean ± SD)

The above results clearly indicate that for all the four trials, seeds exposed to musical sound sprouted faster than untreated control. High significant differences have been observed in seed germination parameters mainly in percentage of sprouted seeds and Mean germination Time (MGT) among the three different experimental seed groups. Indian Classical music stimulated seed groups exhibited highest percentage of sprouted seeds followed by Natural music treated seed groups and untreated control seed groups throughout the elapsed time. At the end of the experiment, only Indian Classical music treated groups showed 100 percent sprouted seeds; while the Natural music treated groups exhibited 90.8% sprouted seeds, and 77.08 % sprouted seeds when averaged over replicates of all the trials. The seed groups also exhibited reduced t50 after music treatments when compared to the untreated control. The Indian Classical Music treated seeds germinated with a lowest MGT of 52.3 hours, Natural Music treated seeds germinated with 54 hours of MGT and the untreated control seeds germinated with highest MGT of 56.6 hours when averaged over replicates of three trials.

6.3.3 EFFECT OF DFA SCALING EXPONENTS ON *Pisum sativum* and *Cicer arietinum* SEED GERMINATION KINETICS

The above experimental results indicate that seed germination kinetics in *Pisum sativum* and *Cicer arietinum* were affected by musical sound of different types. Throughout the experimental period the number of sprouted seeds was much higher in music treated seed groups of both plant species. In case of *Pisum sativum* the Indian Classical music and Natural music with mean DFA exponent value of 1.683 and 1.388 produced 14.9 % increased seed germination compared to the control at the end of the experiment but Indian Classical music exhibited higher germination rate compared to the Natural music. In case of *Cicer arietinum* the Indian Classical music and Natural music treatments produced 29.8% and 17.9%

higher germination than the untreated control at the end. Fig.6.10 and Fig.6.11 depicts the relationship between final increased % of *Pisum sativum* and *Cicer arietinum* germinated seeds at two different music stimulations over control and corresponding DFA scaling exponent values of music signals. The dependence of MGT on DFA exponent value is also very clear in both *Pisum sativum* and *Cicer arietinum* seeds. The Indian Classical Music and Natural Music treatments produced 18.3% and 13 % decreased MGT in *Pisum sativum* (Fig. 6.12); and 7.6% and 4.6% decreased MGT in *Cicer arietinum* over the control (Fig. 6.13).In both cases, a lower DFA exponent value was related to higher MGT.

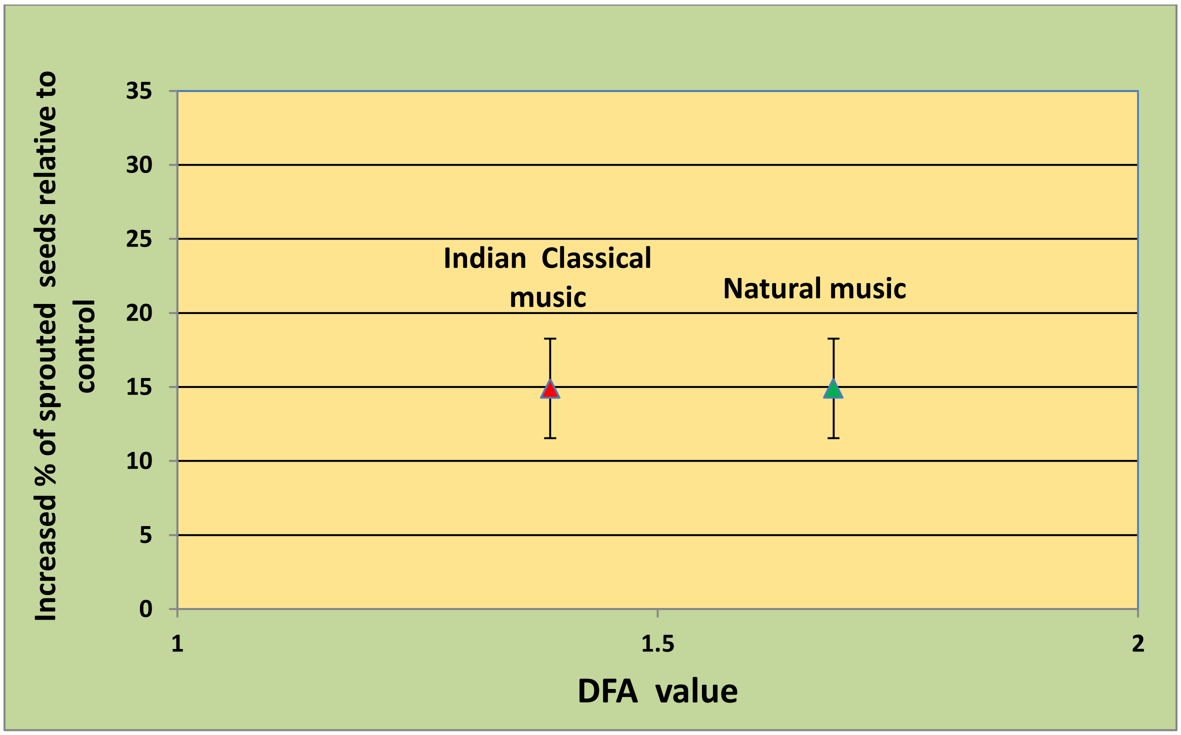


Fig.6.10: Graph depicting increased % of two different music stimulated *Pisum sativum* germinated seeds over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

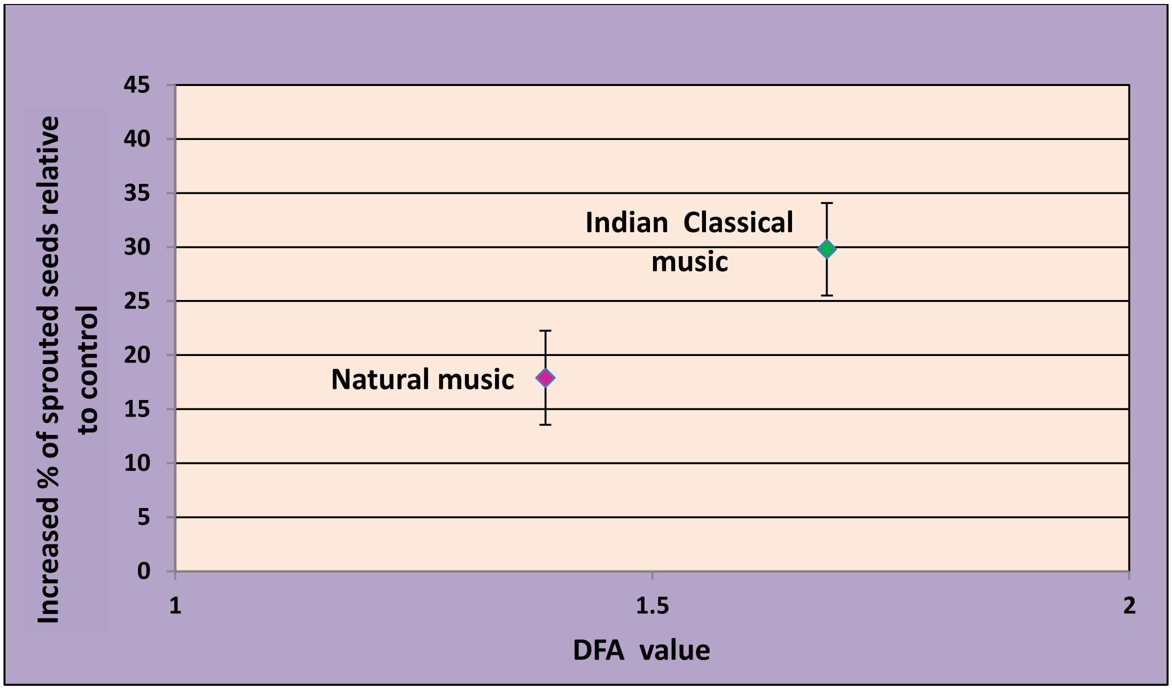


Fig.6.11: Graph depicting increased % of two different music stimulated *Cicer arietinum* germinated seeds over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

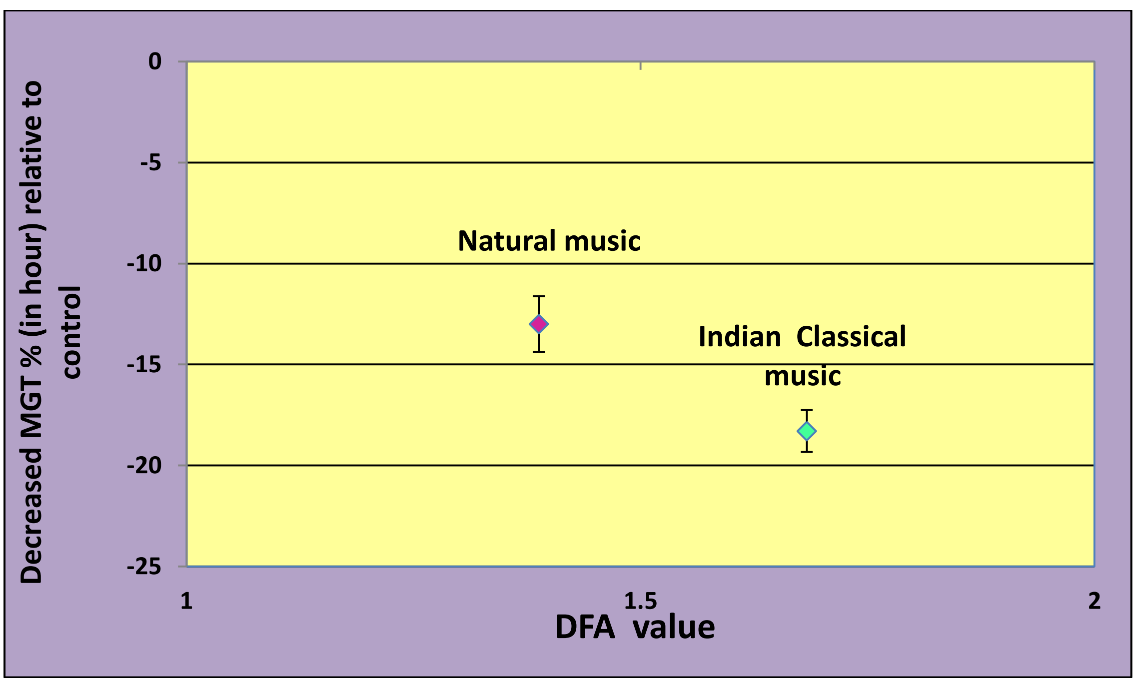


Fig.6.12: Graph comparing decreased Mean Germination Time (MGT) of two different music stimulated *Pisum sativum* seeds over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

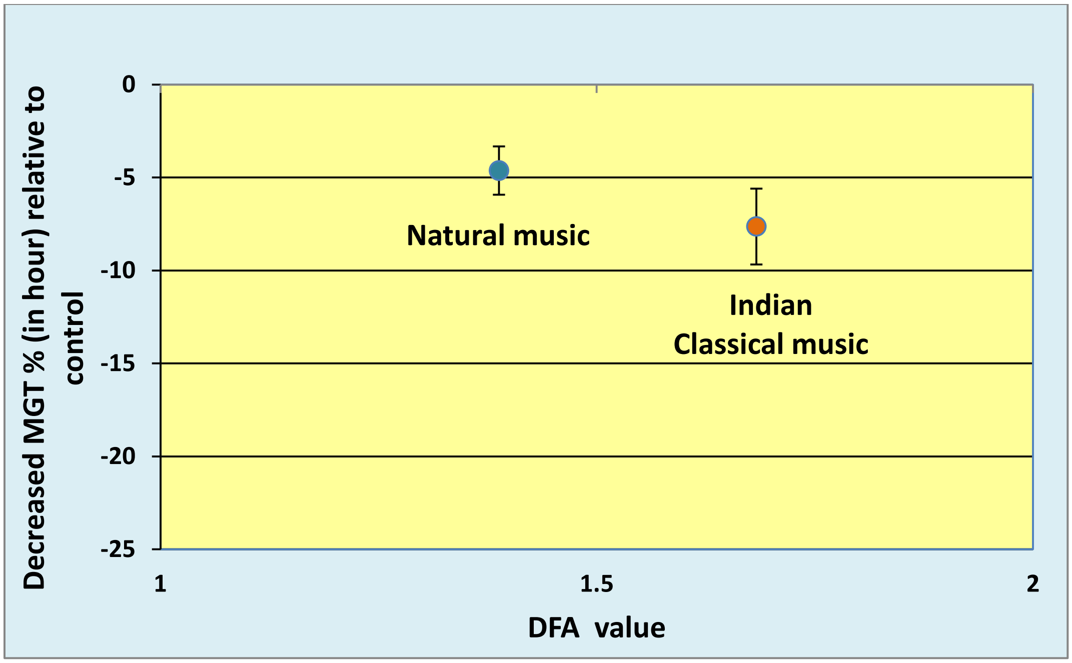


Fig.6.13: Graph comparing decreased Mean Germination Time (MGT) of two different music stimulated *Cicer arietinum* seeds over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

Here, Indian Classical Music had higher long-range temporal correlation (LRTC) compared to Natural Music and interestingly a higher LRTC was associated with lower MGT and greater percentage of sprouted seeds.

6.4 DISCUSSION

From the above results it appears obvious that between the two seed types, *Cicer arietinum* seeds take longer time to begin germination than *Pisum sativum* seeds. *Pisum sativum* seeds began sprouting after 12 hours whereas *Cicer arietinum* seeds take 24 hours. For both kinds of seeds, there was significant effect of conditions (Indian Classical musical sound, Natural musical sound and control) on seed germination. The above results imply that Indian Classical musical sound did indeed had a greater effect on the seed germination kinetics than Natural musical sound when compared to a control with no sound. Musical sounds promoted the speed of germination of both types of seeds relative to an ambient control by increasing germination capacity and reducing germination time and these effects were very much music specific because every music has its own specific spectral characteristics including DFA scaling exponent. This study has concentrated on determining that musical sound of different types had distinct effects on seed germination of same species and also in different plant species as well.The musical sounds chosen for this study promoted germination kinetics in both seed types by increasing the germination capacity and reducing germination time and a higher kinetics was associated with musical sound having higher DFA exponent value.

The domain of response of seed germination to audio signal especially to music stimuli is still unexplored. We present here a serious attempt to ascertain quantitatively a contribution of the musical sound of different acoustical complexities on seed germination taking significant number of controls, samples, as well as with unaltered environmental parameters. It will not be irrelevant to mention that no serious attempt has been reported in this particular field by physicist and botanist till date. From the above experimental results we can conclude that definitely musical sound plays an important role in *Pisum sativum* and *Cicer arietinum* seed germination kinetics. Not only this, musical stimuli with different acoustical complexities have distinguishing effects on seed germination as well.This work has interesting possibilities in biophysics for improving seed germination and enhancing yield.

CHAPTER 7

THE INFLUENCE OF DIFFERENT MUSICAL SOUNDS ON GROWTH OF *Pisum sativum* (PEA) AND *Cicer arietinum* (CHICKPEA/GRAM) PLANTS

7.1 INTRODUCTION

Like germination of seed, growth is another important stage in the life cycle of plant. The review literatures regarding effect of music on plant growth have already been discussed in chapter 2. The primary objective of this study was to observe the effect of different kinds of musical sound on growth of *Pisum sativum* (pea) and *Cicer arietinum* (chickpea) plants. Our second objective was to show the correlation between the growths of plants (in terms of stem length) with acoustical complexity (DFA scaling exponent) in perspective of chaos based analysis of music signal. First experiment was conducted with four different kinds of musical sound to observe the effects on *Pisum sativum* plant growth and with the same methodology the second experiment was with a different species of the same family plant-*Cicer arietinum*.

7.2 METHODOLOGY

7.2.1 DETRENDED FLUCTUATION ANALYSISOF MUSIC SIGNALS

In the present study four different types of music - Indian Classical music, Natural music, Contemporary music and Epic horror music were used as arousal stimuli.Four clips of 3 min each were taken in a way that they convey a variety of moods. The DFA computation follows the method as discussed in chapter 3. It has already mentioned earlier that the DFA scaling exponent is the measure of long range temporal correlation (LRTC) present in a music signal.

7.2.2 EXPERIMENTAL DESIGN FOR MUSIC TREATMENT

To understand the effects of musical sound on growth of plants, four different types of musical sound was played to both *Pisum sativum* and *Cicer arietinum* plants as audio signal during the growth period in special sound proof chambers.

The schematic diagram of experimental set up regarding audio treatment was exactly the same as shown in chapter 5 (Fig.5.1). Each chamber was equipped with uniform speaker and sound amplifier was used to adjust the intensity at 80 dB. Five identical chambers were used for each experiment; four chambers were for four different kinds of music treatments and one was without any music as untreated control chamber. The first experiment was carried out with *Pisum sativum* plants and second experiment was with *Cicer arietinum* plants**.**The methodology remains same for both the experiments. Experiments were based on randomised control design with three replicates of 20 seedlings in each chamber. 300 fully germinated seeds with root and shoot portion equally pierced out from seed coat were taken and potted at equal depth of 2/3th inch inside the soil. Figure 7.1 shows the photograph of sample *Pisum sativum* and *Cicer arietinum* seedlings potted at the beginning of the experiments. All pots were of similar size with equal amount of mud. Seedlings were taken in fifteen separate pots taking 20 in each group. Thus

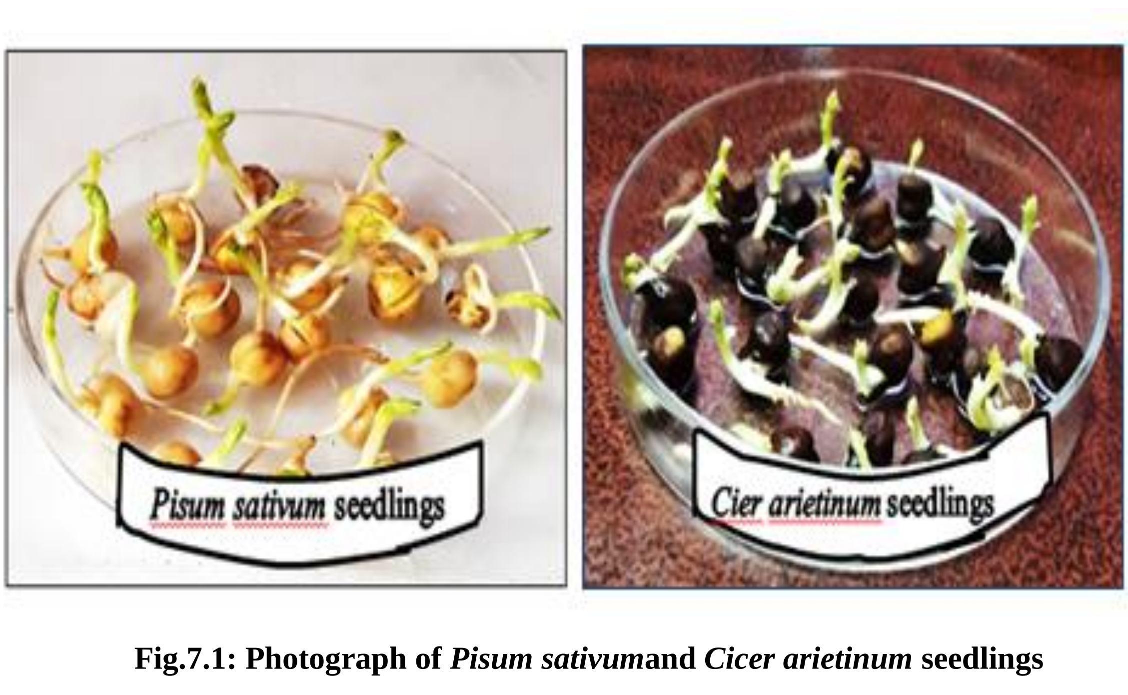


Fig.7.1: Photograph of *Pisum sativum*and *Cicer arietinum* seedlings

four chambers with triplicates of 20 seedlings were subjected to one of the following types of musical sound - Indian Classical music, Natural music, Contemporary music and Epic horror music. One chamber with three groups of 20 seedlings was kept in silence as the control group. The duration and time of music exposure was 3 hours in the early morning between 5:30-8:30 A.M. and 2 hours in the evening between 4:30-6:30 P.M. for a period of 336 hours. Apart from these five hours, all pots of the 5 chambers were kept in identical natural environmental conditions (temperature 26 ± 2^{o}C, and humidity 66 ± 6%). The heights of the plants were noted with the help of a measuring tape in every 48 hours for regular basis till 336 hours and changes up to a millimeter have been noted.

7.3 RESULTS

7.3.1 DFA SCALING EXPONENTS OF MUSIC SIGNALS

DFA was applied on the extracted amplitude envelopes on a moving window basis with a window size of 60s taking an overlap of 50% between the windows. A single scaling exponent α was obtained corresponding to each window of 60 seconds.Table 7.1 shows the variation of DFA Scaling Exponents for the four different musical stimuli-Indian Classical music, Natural music, Contemporary music, and Epic horror music used in our study. It is clear from the table that each genre of music has its very specific pattern of scaling or self-similarity which leads to a complete distinctive pattern in their DFA scaling exponent. Herein lays the originality of that musical clip, each of which creates a completely different mood and ambiance very distinctive from the other, the basics of which are hidden in the complex waveform possessed by each. The clip used for Indian Classical musichas the highest order of self-similarity while the Epic Horror has the lowest degree of self-similarity. The clip with Natural music and the Contemporary music have

LRTC which lies somewhere in between the two; with the Hurst Exponent of Contemporary music being on the lower side while that of the Natural music on the higher side. This significant variation in the scaling pattern leads to distinct differences in the perception of the living organisms that are made to listen to these music clips.

Table 7.1: Variation of DFA scaling exponent for different parts of 4 musical stimuli

	DFA scaling exponent			
	Clip 1 Indian Classical music	**Clip 2 Natural music**	**Clip 3 Contemporary Music**	**Clip 4 Epic Horror Music**
Part 1	1.652	1.277	0.764	0.238
Part 2	1.584	1.489	0.812	0.207
Part 3	1.815	1.398	0.758	0.206

7.3.2 GROWTH ANALYSIS

The morphological changes observed in heights of the plants all over the experiments. The recorded data taken after every 48 hours helped to distinguish differences between stem lengths of *Pisum sativum* and *Cicer arietinum* seedlings subjected to different kinds of music verses control till 336 hours. Thereafter no significant phenotypic changes were seen in plant height. From these data differences in growth rate percentage of four music treated plants relative to untreated control plants were calculated. The relation between growths of plant with DFA scaling exponents of treated musical sounds were also elucidated from the data. Graphs were also drawn from these data to make the results more apprehensible and to explicate easily.

7.3.2.1 GROWTH ANALYSIS IN *Pisum sativum* PLANT

Figure 7.2 shows the photograph of four different musical sounds treated and control *Pisum sativum* plants after 96 hours (Replicate-1). Table 7.2, Table 7.3, Table 7.4, Table 7.5, and Table 7.6 shows the replicate-1 raw data of *Pisum sativum* plant growthin terms of stem length in cm. with time in hours for Indian Classical music, Natural music, Contemporary music, Epic Horror music, and Control group respectively. Table 7.7, Table 7.8, Table 7.9, Table 7.10, and Table 7.11 displays the replicate-2 data; and Table 7.12, Table 7.13, Table 7.14, Table 7.15 and Table 7.16 are the same for replicate- 3.Table 7.17 shows the growth of control and four different kinds of music treated pea plants measured after 48, 96, 144, 192, 240, 288, and 336 hours averaged over plants of all the replicates. From the table it is clear that all the music treated plants showed better results than untreated control except Epic Horror music treated plants. The Indian Classical music treated plants exhibited highest growthsthroughout the experimental time period compared to the other treated plants. Up to 144 hours the Natural music exposed plants showed better growth result than the Contemporary and Epic horror treated plants. But after 192 hours the average stem length of both the Natural music and Contemporary music subjected plants were almost equal. Again 240 hours onwards the Natural music treated plants showed higher growth than the Contemporary music treated plants. Interestingly Epic Horror music treated plants responded quite differently. Up to 288 hours the plants exhibited lower growth than the control plants, but at the end of the experiment the Epic Horror music subjected plants showed slightly higher growth than the untreated control plants.

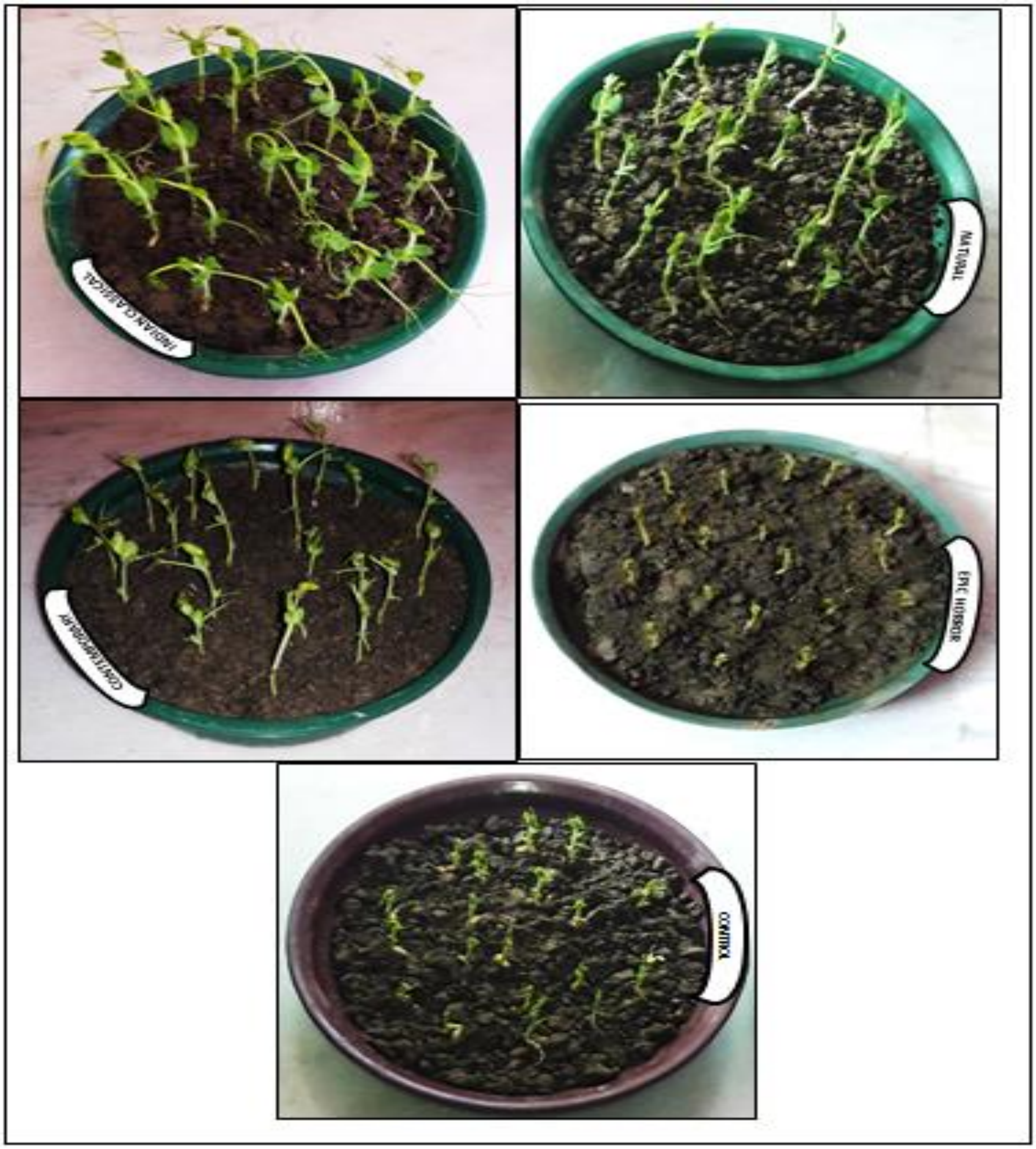


Fig.7.2: Photograph of control and different music treated *Pisum sativum* plants after 96 hours (Replicate 1)

Replicate-1

Table 7.2: Indian Classical music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.6	5.3	12.8	18.8	24.9	29.7	34.8
2	2.5	5.3	12.7	18.7	24.8	29.8	34.8
3	2.7	5.4	12.8	18.8	24.8	29.8	34.7
4	2.7	5.4	12.8	18.9	24.8	29.7	34.8
5	2.7	5.3	12.8	18.8	24.9	29.7	34.7
6	2.6	5.3	12.8	18.7	24.9	29.8	34.7
7	2.5	5.2	12.7	18.8	24.9	29.7	34.7
8	2.6	5.3	12.8	18.7	24.8	29.8	34.9
9	2.6	5.4	12.9	18.7	24.9	29.8	34.8
10	2.6	5.2	12.7	18.8	24.7	29.8	34.8
11	2.7	5.4	12.8	18.9	24.8	29.8	34.7
12	2.5	5.3	12.8	18.7	24.8	29.8	34.8
13	2.5	5.2	12.7	18.7	24.8	29.7	34.7
14	2.6	5.2	12.7	18.9	24.8	29.8	34.8
15	2.7	5.4	12.9	18.9	24.9	29.9	34.8
16	2.7	5.3	12.8	18.8	24.7	29.8	34.7
17	2.5	5.2	12.7	18.7	24.7	29.7	34.7
18	2.5	5.3	12.8	18.7	24.8	29.7	34.7
19	2.7	5.4	12.8	18.7	24.7	29.7	34.8
20	2.5	5.3	12.8	18.8	24.8	29.8	34.7
Sum	52.0	106.1	255.6	375.5	496.2	595.3	695.1
Mean±SD	2.6±0.08	5.30±0.07	12.78±0.06	18.77±0.07	24.81±0.07	29.76±0.05	34.75±0.05

Replicate-1

Table 7.3: Natural music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 Hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	5.0	11.3	16.3	22.5	28.5	32.5
2	2.3	4.9	11.2	16.3	22.4	28.4	32.5
3	2.3	4.8	11.2	16.2	22.4	28.4	32.5
4	2.3	4.9	11.3	16.3	22.4	28.6	32.6
5	2.4	4.9	11.2	16.2	22.3	28.4	32.4
6	2.4	5.0	11.2	16.4	22.5	28.4	32.4
7	2.4	5.0	11.3	16.4	22.5	28.6	32.4
8	2.5	5.0	11.3	16.4	22.5	28.5	32.5
9	2.3	4.8	11.2	16.3	22.4	28.5	32.6
10	2.4	5.0	11.4	16.4	22.4	28.5	32.5
11	2.3	4.9	11.3	16.3	22.5	28.5	32.5
12	2.4	4.9	11.2	16.3	22.4	28.4	32.5
13	2.3	4.9	11.3	16.3	22.3	28.4	32.5
14	2.4	4.9	11.3	16.4	22.4	28.5	32.5
15	2.3	4.8	11.2	16.2	22.4	28.5	32.6
16	2.4	5.0	11.3	16.2	22.3	28.4	32.6
17	2.3	4.8	11.2	16.3	22.4	28.5	32.5
18	2.3	4.9	11.3	16.4	22.4	28.6	32.5
19	2.4	5.0	11.4	16.4	22.3	28.5	32.5
20	2.4	4.9	11.3	16.3	22.4	28.5	32.4
Sum	47.2	98.3	225.4	326.3	448.1	569.6	650.0
Mean±SD	2.36±0.05	4.915±0.07	11.27±0.06	16.31±0.07	22.40±0.06	28.48±0.06	32.5±0.06

Replicate-1

Table 7.4: Contemporary music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 Hours	96 Hours	144 Hours	192 hours	240 hours	288 hours	336 Hours
1	2.2	4.6	10.3	16.2	22.3	27.3	31.4
2	2.3	4.7	10.4	16.2	22.3	27.3	31.4
3	2.3	4.6	10.3	16.2	22.3	27.2	31.3
4	2.4	4.7	10.3	16.4	22.4	27.3	31.2
5	2.2	4.6	10.4	16.3	22.3	27.2	31.3
6	2.4	4.7	10.3	16.3	22.3	27.3	31.3
7	2.3	4.6	10.3	16.2	22.2	27.3	31.4
8	2.2	4.6	10.3	16.3	22.4	27.4	31.4
9	2.3	4.6	10.2	16.2	22.3	27.4	31.5
10	2.3	4.6	10.3	16.2	22.2	27.2	31.4
11	2.3	4.6	10.3	16.3	22.3	27.4	31.3
12	2.2	4.5	10.2	16.2	22.2	27.3	31.3
13	2.3	4.7	10.3	16.2	22.2	27.3	31.2
14	2.4	4.7	10.4	16.3	22.3	27.2	31.3
15	2.3	4.7	10.3	16.2	22.2	27.3	31.3
16	2.2	4.6	10.3	16.2	22.3	27.4	31.4
17	2.3	4.6	10.3	16.3	22.4	27.4	31.4
18	2.3	4.7	10.3	16.4	22.4	27.4	31.3
19	2.2	4.6	10.3	16.3	22.3	27.3	31.3
20	2.2	4.6	10.2	16.2	22.3	27.2	31.3
Sum	45.6	92.6	206.0	325.1	445.9	546.1	626.7
Mean±SD	2.28±0.06	4.63±0.05	10.3±0.05	16.25±0.06	22.29±0.06	27.30±0.07	31.33±0.07

Replicate-1

Table 7.5: Epic Horror music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.0	1.9	3.7	7.6	13.7	19.6	25.7
2	0.9	1.7	3.6	7.6	13.6	19.7	25.8
3	1.0	1.8	3.6	7.5	13.5	19.6	25.7
4	0.8	1.7	3.5	7.5	13.6	19.6	25.7
5	0.9	1.7	3.6	7.7	13.6	19.7	25.7
6	0.9	1.7	3.5	7.5	13.5	19.6	25.7
7	0.8	1.6	3.5	7.6	13.5	19.7	25.7
8	0.8	1.7	3.5	7.5	13.6	19.7	25.7
9	1.0	1.8	3.6	7.5	13.5	19.6	25.8
10	1.0	1.9	3.7	7.7	13.6	19.6	25.6
11	1.0	1.9	3.7	7.7	13.7	19.8	25.8
12	1.0	1.8	3.6	7.6	13.5	19.6	25.7
13	0.9	1.8	3.6	7.5	13.6	19.6	25.6
14	0.9	1.8	3.7	7.5	13.6	19.7	25.6
15	0.8	1.6	3.5	7.6	13.6	19.6	25.6
16	0.9	1.7	3.5	7.7	13.6	19.7	25.6
17	0.9	1.7	3.6	7.6	13.5	19.6	25.6
18	0.8	1.7	3.6	7.7	13.6	19.6	25.6
19	0.9	1.7	3.5	7.7	13.7	19.6	25.7
20	1.0	1.8	3.6	7.7	13.6	19.6	25.5
Sum	18.2	35.0	71.7	152.0	271.7	392.8	513.4
Mean±SD	0.91±0.07	1.75±0.08	3.585±0.07	7.6±0.08	13.58±0.06	19.64±0.05	25.67±0.07

Replicate-1

Table7.6: *Pisum sativum* plant growth in terms of stem length in cm. with time in hours without any music stimuli

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.7	3.6	7.5	12.7	17.2	21.2	25.3
2	1.9	3.8	7.6	12.6	17.1	21.2	25.2
3	1.9	3.7	7.6	12.7	17.1	21.2	25.3
4	1.8	3.7	7.6	12.7	17.2	21.2	25.3
5	1.8	3.8	7.7	12.7	17.2	21.1	25.2
6	1.9	3.8	7.7	12.8	17.3	21.2	25.2
7	1.9	3.8	7.6	12.7	17.1	21.3	25.4
8	1.8	3.6	7.4	12.6	17.1	21.2	25.3
9	1.7	3.6	7.4	12.6	17.1	21.3	25.4
10	1.9	3.7	7.6	12.7	17.2	21.2	25.4
11	1.8	3.7	7.6	12.6	17.1	21.2	25.3
12	1.9	3.8	7.7	12.6	17.0	21.2	25.3
13	1.9	3.7	7.6	12.7	17.2	21.3	25.3
14	1.8	3.6	7.5	12.6	17.1	21.2	25.2
15	1.8	3.6	7.5	12.7	17.2	21.3	25.3
16	1.9	3.8	7.7	12.8	17.2	21.3	25.4
17	1.8	3.7	7.6	12.8	17.3	21.3	25.4
18	1.9	3.8	7.7	12.8	17.2	21.2	25.3
19	1.7	3.6	7.5	12.7	17.2	21.2	25.4
20	1.9	3.7	7.6	12.8	17.3	21.2	25.2
Sum	36.7	74.1	151.7	253.9	343.4	424.5	56.1
Mean±SD	1.83±0.07	3.70±0.08	7.58±0.09	12.69±0.07	17.17±0.07	21.22±0.05	25.30±0.07

Replicate-2

Table 7.7: Indian Classical music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	5.0	12.5	18.7	24.7	29.7	34.7
2	2.4	5.0	12.6	18.7	24.8	29.8	34.9
3	2.6	5.1	12.7	18.7	24.7	29.8	34.8
4	2.4	5.0	12.6	18.8	24.8	29.8	34.8
5	2.6	5.2	12.8	18.8	24.8	29.7	34.9
6	2.6	5.2	12.7	18.7	24.7	29.8	34.9
7	2.5	5.1	12.6	18.8	24.8	29.9	34.9
8	2.5	5.0	12.6	18.7	24.9	29.9	34.9
9	2.5	5.0	12.5	18.7	24.8	29.8	34.8
10	2.6	5.1	12.7	18.8	24.9	29.8	34.8
11	2.5	5.1	12.6	18.7	24.7	29.8	34.9
12	2.6	5.2	12.7	18.7	24.8	29.8	34.8
13	2.5	5.1	12.6	18.7	24.8	29.8	34.7
14	2.6	5.2	12.7	18.8	24.9	29.8	34.8
15	2.6	5.3	12.8	18.7	24.8	29.9	34.8
16	2.5	5.1	12.7	18.8	24.8	29.8	34.9
17	2.5	5.2	12.8	18.9	24.8	29.9	34.9
18	2.5	5.1	12.6	18.8	24.8	29.8	34.7
19	2.6	5.2	12.7	18.9	24.9	29.8	34.9
20	2.6	5.2	12.7	18.8	24.8	29.9	34.9
Sum	50.7	102.4	253.2	375.2	496.0	596.3	696.7
Mean±SD	2.53±0.06	5.12±0.08	12.66±0.08	18.76±0.06	24.8±0.06	29.81±0.05	34.83±0.07

Replicate-2

Table 7.8: Natural music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.9	11.2	16.3	22.3	28.2	32.4
2	2.4	5.0	11.3	16.2	22.3	28.3	32.3
3	2.3	4.9	11.3	16.3	22.2	28.2	32.3
4	2.3	4.9	11.2	16.3	22.3	28.2	32.2
5	2.4	5.0	11.2	16.2	22.3	28.3	32.2
6	2.4	5.1	11.3	16.3	22.4	28.4	32.3
7	2.3	4.9	11.3	16.2	22.4	28.3	32.3
8	2.5	5.0	11.4	16.3	22.4	28.4	32.3
9	2.3	4.8	11.0	16.1	22.3	28.3	32.2
10	2.5	5.2	11.4	16.3	22.2	28.2	32.4
11	2.3	5.0	11.3	16.2	22.4	28.3	32.2
12	2.5	5.1	11.2	16.1	22.2	28.2	32.2
13	2.5	5.1	11.3	16.2	22.2	28.2	32.3
14	2.4	5.1	11.2	16.3	22.2	28.2	32.4
15	2.4	5.0	11.3	16.3	22.3	28.2	32.2
16	2.4	5.0	11.3	16.3	22.3	28.3	32.4
17	2.5	5.1	11.4	16.4	22.3	28.3	32.3
18	2.3	5.0	11.2	16.3	22.2	28.3	32.3
19	2.4	5.0	11.3	16.2	22.4	28.4	32.4
20	2.3	4.9	11.2	16.2	22.3	28.4	32.4
Sum	47.8	100.0	225.3	325.0	445.9	565.6	646.0
Mean±SD	2.39±0.07	5.0±0.09	11.26±0.09	16.25±0.07	22.29±0.07	28.28±0.07	32.3±0.07

Replicate-2

Table 7.9: Contemporary music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.4	10.2	16.2	22.3	27.3	31.2
2	2.2	4.4	10.2	16.3	22.3	27.4	31.3
3	2.3	4.5	10.2	16.2	22.2	27.3	31.3
4	2.3	4.6	10.3	16.3	22.2	27.2	31.3
5	2.2	4.5	10.3	16.3	22.2	27.2	31.2
6	2.3	4.5	10.3	16.4	22.3	27.2	31.3
7	2.2	4.4	10.2	16.4	22.4	27.4	31.3
8	2.3	4.5	10.3	16.3	22.4	27.4	31.4
9	2.3	4.6	10.4	16.4	22.4	27.3	31.4
10	2.2	4.5	10.4	16.3	22.2	27.3	31.3
11	2.3	4.6	10.4	16.3	22.3	27.3	31.3
12	2.2	4.4	10.3	16.4	22.3	27.4	31.3
13	2.2	4.5	10.3	16.3	22.3	27.3	31.2
14	2.3	4.5	10.4	16.3	22.4	27.3	31.2
15	2.3	4.6	10.4	16.3	22.4	27.4	31.3
16	2.2	4.5	10.3	16.4	22.4	27.4	31.3
17	2.2	4.4	10.2	16.3	22.4	27.3	31.3
18	2.3	4.6	10.4	16.4	22.3	27.3	31.4
19	2.3	4.5	10.3	16.3	22.4	27.4	31.3
20	2.3	4.6	10.4	16.3	22.3	27.2	31.2
Sum	45.2	90.1	206.2	326.4	446.4	546.3	625.8
Mean±SD	2.26±0.04	4.50±0.07	10.31±0.07	16.32±0.06	22.32±0.07	27.31±0.07	31.29±0.06

Replicate-2

Table 7.10: Epic Horror music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	0.9	1.6	3.2	7.1	13.4	19.7	25.7
2	0.9	1.6	3.1	7.0	13.3	19.7	25.6
3	0.8	1.5	3.0	7.0	13.3	19.6	25.6
4	0.8	1.5	3.0	7.0	13.4	19.6	25.7
5	0.8	1.5	3.1	7.1	13.3	19.6	25.7
6	0.9	1.5	3.0	7.0	13.2	19.5	25.6
7	0.8	1.4	3.0	7.2	13.3	19.6	25.6
8	0.8	1.5	3.0	7.0	13.3	19.7	25.8
9	0.8	1.5	3.0	7.0	13.4	19.7	25.8
10	0.9	1.6	3.0	7.0	13.3	19.7	25.7
11	1.0	1.6	3.1	7.1	13.4	19.7	25.6
12	1.0	1.7	3.2	7.2	13.4	19.7	25.7
13	0.9	1.6	3.1	7.2	13.3	19.6	25.7
14	0.9	1.6	3.0	7.0	13.2	19.6	25.7
15	0.8	1.5	3.1	7.1	13.3	19.6	25.6
16	0.9	1.6	3.2	7.1	13.4	19.7	25.8
17	0.9	1.6	3.1	7.0	13.3	19.7	25.8
18	0.9	1.5	3.0	7.0	13.3	19.7	25.7
19	0.8	1.4	3.0	7.0	13.4	19.7	25.8
20	0.9	1.6	3.1	7.1	13.3	19.6	25.7
Sum	17.4	30.9	61.3	141.2	266.5	393.0	513.9
Mean±SD	0.87±0.06	1.54±0.07	3.06±0.07	7.06±0.07	13.32±0.06	19.65±0.05	25.69±0.07

<u>Replicate-2</u>

Table 7.11: *Pisum sativum* plant growth in terms of stem length in cm. with time in hours without any music stimuli

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.9	3.8	7.6	12.7	17.0	21.0	25.2
2	1.8	3.7	7.6	12.6	17.0	21.1	25.2
3	1.9	3.8	7.6	12.7	17.1	21.0	25.0
4	1.9	3.8	7.7	12.6	17.1	21.1	25.1
5	1.8	3.7	7.5	12.6	17.0	21.0	25.1
6	1.8	3.6	7.5	12.6	17.0	21.0	25.1
7	1.7	3.6	7.4	12.6	17.0	21.1	25.2
8	1.7	3.6	7.5	12.6	17.1	21.1	25.1
9	1.9	3.8	7.5	12.7	17.2	21.1	25.2
10	1.9	3.7	7.5	12.8	17.2	21.2	25.2
11	1.8	3.6	7.4	12.6	17.1	21.2	25.2
12	1.8	3.6	7.4	12.5	17.0	21.1	25.2
13	1.9	3.7	7.5	12.5	17.0	21.0	25.1
14	1.9	3.7	7.5	12.8	17.2	21.2	25.2
15	1.7	3.6	7.4	12.7	17.2	21.2	25.0
16	1.7	3.6	7.4	12.6	17.0	21.0	25.0
17	1.7	3.5	7.4	12.7	17.0	21.0	25.1
18	1.7	3.6	7.4	12.5	17.0	21.1	25.2
19	1.8	3.6	7.4	12.5	17.1	21.0	25.1
20	1.9	3.7	7.5	12.6	17.0	21.1	25.1
Sum	36.2	73.3	149.7	252.5	341.3	421.6	502.6
Mean±SD	1.81±0.08	3.66±0.08	7.485±0.08	12.62±0.08	17.06±0.07	21.08±0.07	25.13±0.07

Replicate-3

Table 7.12: Indian Classical music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.7	5.5	12.9	18.9	24.9	30.0	34.9
2	2.8	5.5	12.9	18.9	24.9	30.0	35.0
3	2.8	5.6	13.0	18.9	25.0	30.0	35.1
4	2.7	5.5	12.9	19.0	25.0	29.9	35.0
5	2.7	5.5	12.8	19.0	24.9	29.9	35.0
6	2.7	5.5	12.9	19.0	25.0	29.9	34.9
7	2.6	5.4	12.8	18.9	24.9	30.0	34.9
8	2.7	5.6	13.0	18.9	24.9	30.0	35.0
9	2.8	5.6	12.9	19.0	24.9	29.9	35.0
10	2.8	5.5	12.8	19.0	24.9	30.0	34.9
11	2.7	5.5	12.9	19.0	25.0	29.9	34.9
12	2.7	5.5	13.0	18.9	25.0	30.0	35.0
13	2.7	5.4	12.9	18.9	24.9	30.0	34.9
14	2.8	5.6	12.9	19.0	24.9	29.9	35.0
15	2.8	5.6	13.0	19.0	25.0	30.0	35.0
16	2.7	5.5	12.9	19.0	25.0	30.0	34.9
17	2.7	5.5	13.0	19.0	24.9	29.9	35.1
18	2.8	5.6	13.0	18.9	24.8	29.9	35.0
19	2.7	5.5	12.9	18.9	25.0	29.9	35.0
20	2.8	5.6	13.0	18.9	24.9	29.9	35.0
Sum	54.7	110.5	258.4	379	498.7	599.0	699.5
Mean±SD	2.73±0.05	5.52±0.06	12.92±0.06	18.95±0.05	24.93±0.05	29.95±0.05	34.97±0.06

Replicate-3

Table 7.13: Natural music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.5	5.1	11.5	16.5	22.5	28.6	32.5
2	2.5	5.1	11.4	16.5	22.5	28.5	32.5
3	2.5	5.0	11.5	16.6	22.5	28.5	32.5
4	2.4	5.0	11.4	16.6	22.6	28.6	32.6
5	2.3	4.9	11.3	16.5	22.6	28.5	32.6
6	2.3	4.9	11.3	16.5	22.5	28.6	32.6
7	2.3	4.9	11.3	16.4	22.5	28.5	32.5
8	2.5	5.1	11.4	16.6	22.6	28.5	32.6
9	2.3	4.9	11.3	16.5	22.5	28.6	32.6
10	2.4	4.9	11.4	16.6	22.5	28.4	32.5
11	2.4	5.0	11.4	16.6	22.5	28.4	32.5
12	2.3	4.9	11.3	16.5	22.5	28.4	32.5
13	2.3	4.8	11.3	16.6	22.6	28.5	32.5
14	2.3	4.9	11.3	16.4	22.5	28.5	32.6
15	2.4	5.0	11.4	16.5	22.5	28.5	32.5
16	2.4	5.0	11.5	16.6	22.5	28.6	32.5
17	2.5	5.1	11.5	16.6	22.6	28.6	32.6
18	2.3	4.9	11.4	16.5	22.5	28.6	32.5
19	2.4	4.9	11.3	16.4	22.5	28.6	32.6
20	2.4	4.9	11.4	16.6	22.6	28.5	32.6
Sum	47.7	99.2	227.6	330.6	450.6	570.5	650.9
Mean±SD	2.38±0.07	4.96±0.08	11.38±0.07	16.53±0.07	22.53±0.04	28.52±0.06	32.54±0.04

Replicate-3

Table 7.14: Contemporary music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.4	4.8	10.6	16.5	22.5	27.4	31.5
2	2.2	4.6	10.4	16.5	22.5	27.5	31.5
3	2.2	4.6	10.4	16.5	22.6	27.5	31.5
4	2.3	4.7	10.6	16.6	22.6	27.6	31.6
5	2.3	4.5	10.4	16.6	22.6	27.6	31.6
6	2.3	4.6	10.5	16.6	22.5	27.5	31.6
7	2.3	4.7	10.6	16.7	22.6	27.6	31.6
8	2.2	4.6	10.4	16.5	22.6	27.5	31.5
9	2.3	4.6	10.4	16.5	22.5	27.5	31.5
10	2.4	4.7	10.4	16.5	22.5	27.6	31.6
11	2.4	4.6	10.5	16.6	22.6	27.6	31.6
12	2.4	4.8	10.6	16.7	22.7	27.7	31.6
13	2.3	4.7	10.5	16.6	22.6	27.6	31.7
14	2.3	4.7	10.5	16.6	22.6	27.6	31.6
15	2.4	4.8	10.5	16.6	22.6	27.6	31.6
16	2.4	4.7	10.6	16.7	22.6	27.7	31.7
17	2.2	4.6	10.4	16.5	22.6	27.7	31.6
18	2.2	4.5	10.4	16.6	22.5	27.6	31.6
19	2.3	4.6	10.4	16.6	22.6	27.7	31.7
20	2.3	4.7	10.6	16.7	22.7	27.6	31.7
Sum	46.1	93.1	209.7	331.7	451.6	551.7	631.9
Mean±SD	2.30±0.07	4.65±0.08	10.48±0.08	16.58±0.07	22.58±0.06	27.585±0.07	31.59±0.06

Replicate-3

Table 7.15: Epic Horror music treated *Pisum sativum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	0.7	1.4	3.0	7.1	13.0	19.4	25.7
2	0.8	1.4	3.0	7.0	13.1	19.4	25.7
3	0.8	1.4	3.0	7.0	13.0	19.3	25.7
4	0.8	1.5	3.2	7.1	13.1	19.4	25.8
5	0.7	1.3	3.0	7.0	13.0	19.4	25.7
6	0.7	1.3	3.1	7.0	13.0	19.3	25.6
7	0.8	1.5	3.1	7.0	13.1	19.4	25.7
8	0.8	1.4	3.0	6.9	13.0	19.3	25.6
9	0.7	1.3	3.0	7.0	13.2	19.5	25.8
10	0.8	1.4	3.0	7.1	13.2	19.4	25.8
11	0.8	1.4	3.0	7.0	13.1	19.4	25.7
12	0.7	1.3	2.9	6.9	13.0	19.3	25.6
13	0.9	1.5	3.2	7.1	13.2	19.5	25.8
14	0.9	1.5	3.1	7.1	13.2	19.5	25.8
15	0.8	1.5	3.2	7.1	13.1	19.4	25.7
16	0.9	1.5	3.1	7.1	13.0	19.3	25.7
17	0.9	1.4	3.0	7.0	13.0	19.4	25.7
18	0.7	1.3	3.0	7.0	13.1	19.4	25.6
19	0.8	1.4	3.0	7.1	13.2	19.5	25.8
20	0.9	1.5	3.1	7.1	13.0	19.3	25.6
Sum	15.9	28.2	61.0	140.7	261.6	387.8	514.1
Mean±SD	0.79±0.07	1.41±0.05	3.05±0.08	7.03±0.06	13.08±0.08	19.39±0.07	25.70±0.07

Replicate-3

Table 7.16: *Pisum sativum* plant growth in terms of stem length in cm. with time in hours without any music stimuli

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.0	3.9	7.7	12.9	17.4	21.5	25.4
2	1.9	3.9	7.8	12.9	17.3	21.3	25.3
3	1.9	3.8	7.6	12.8	17.3	21.3	25.4
4	1.9	3.8	7.7	12.9	17.4	21.5	25.4
5	1.8	3.7	7.6	12.8	17.3	21.4	25.5
6	2.0	3.9	7.8	12.9	17.4	21.4	25.4
7	1.9	3.8	7.7	12.8	17.3	21.4	25.3
8	1.8	3.7	7.6	12.8	17.2	21.3	25.4
9	1.8	3.7	7.6	12.9	17.3	21.3	25.4
10	1.9	3.9	7.8	12.9	17.2	21.3	25.3
11	1.9	3.9	7.8	12.8	17.3	21.4	25.4
12	1.8	3.7	7.6	12.8	17.2	21.4	25.4
13	2.0	3.9	7.6	12.9	17.3	21.4	25.4
14	2.0	3.9	7.7	12.9	17.4	21.4	25.3
15	1.9	3.8	7.7	12.8	17.2	21.4	25.4
16	1.9	3.8	7.6	12.8	17.2	21.3	25.4
17	1.9	3.9	7.7	12.9	17.4	21.5	25.5
18	1.8	3.8	7.6	12.8	17.3	21.4	25.4
19	1.8	3.7	7.6	12.8	17.2	21.4	25.3
20	2.0	3.9	7.7	12.8	17.3	21.4	25.4
Sum	37.9	76.4	153.5	256.9	345.9	427.7	507.7
Mean±SD	1.89±0.07	3.82±0.08	7.67±0.07	12.84±0.04	17.29±0.07	21.38±0.06	25.38±0.05

Table 7.17: *Pisum sativum* plant growth (stem length in cm.) with time (in hours) averaged over all the replicates

	Control	Indian Classical music	Natural music	Contemporary music	Epic Horror music
48 hours	1.8±0.08	2.6±0.1	2.3±0.07	2.2±0.06	0.8±0.08
96 hours	3.7±0.1	5.3±0.18	4.9±0.09	4.5±0.09	1.5±0.16
144 hours	7.5±0.11	12.7±0.12	11.3±0.09	10.3±0.11	3.2±0.26
192 hours	12.7±0.11	18.8±0.1	16.3±0.14	16.3±0.15	7.2±0.27
240 hours	17.1±0.12	24.8±0.08	22.4±0.11	22.3±0.14	13.3±0.21
288 hours	21.2±0.14	29.8±0.09	28.4±0.12	27.4±0.15	19.5±0.13
336 Hours	25.2±0.12	34.8±0.11	32.4±0.12	31.4±0.15	25.6±0.07

Figure 7.3 is the graphical representation of table 7.17. Figure 7.4 has drawn from the above table data to evaluate the differences in average plant growth (in percentage) of four music treated *Pisum sativum* plants relative to the untreated control after 48, 96, 144, 192, 240, 288, and 336 hour. At the end of the experiment, the average stem length of plants exposed to Indian Classical music, Natural music, Contemporary music, and Epic Horror music was 38.09%, 28.5%, 24.6% and 1.5 % higher than the untreated control plants.

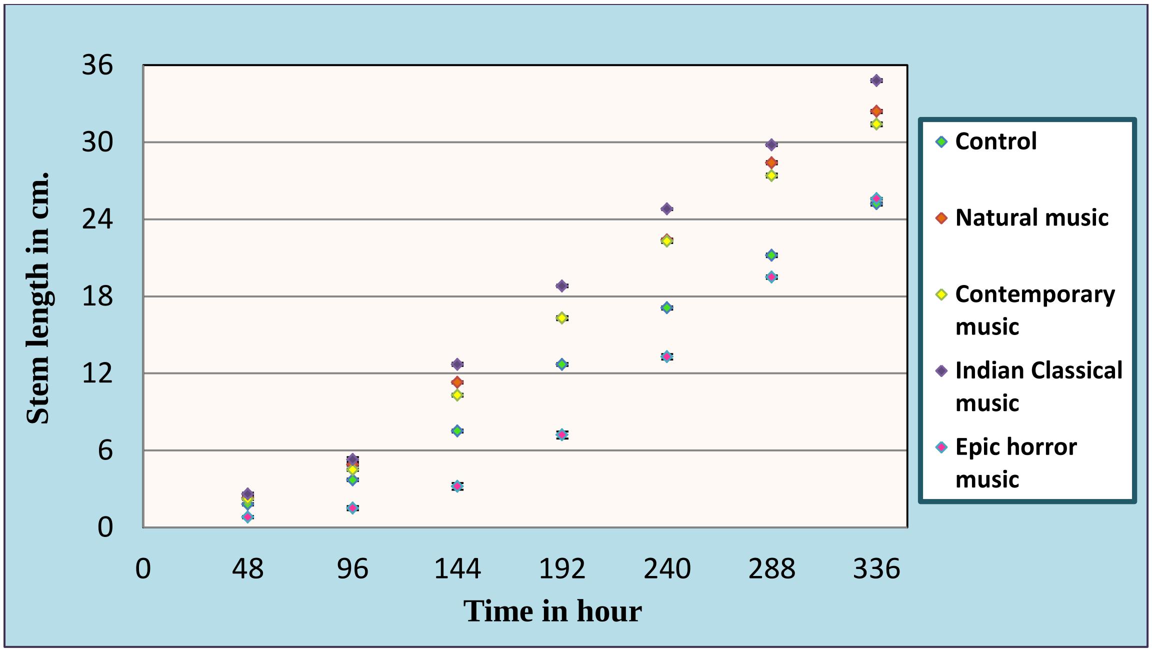


Fig.7.3: Graph showing average stem length of control and different music treated *Pisum sativum* plants versus time (Vertical bars represent mean ± SD)

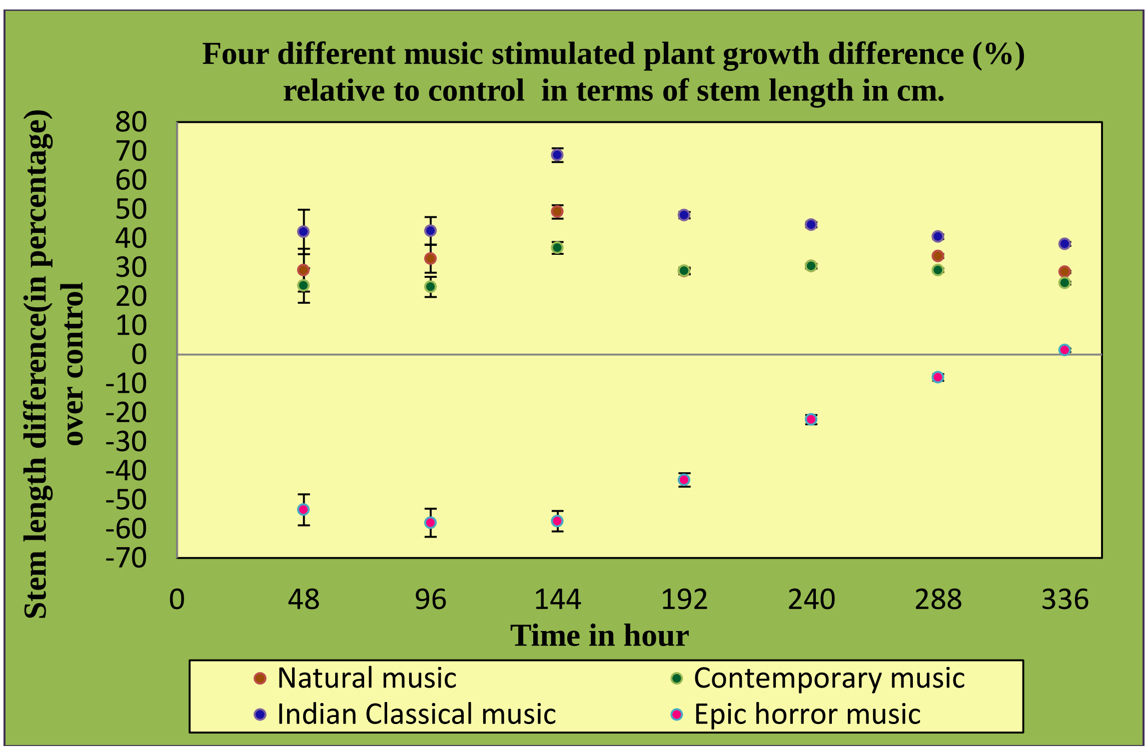


Fig.7.4: Graph showing differences in average stem length (percentage) of four different musical sound treated *Pisum sativum* plants relative to control versus time (Vertical bars represent mean ± SD)

6.3.2.2 GROWTH ANALYSIS IN *Cicer arietinum* PLANT

Figure 7.5 shows the photograph of four different kinds of musical sound treated and control plants after 96 hours (Replicate-1). The detailed replicate-1 data of *Cicer arietinum* plant growthin terms of stem length in cm. with time in hours have been shown in Table 7.18 for Indian Classical music, Table 7.19 for Natural music, Table 7.20 for Contemporary music, Table 7.21 for Epic horror music, and Table 7.22 for Control group respectively. Table 7.23, Table 7.24, Table 7.25, Table 7.26 and Table 7.27 are the same for replicate-2; Table 7.28, Table 7.29, Table 7.30, Table 7.31 and Table 7.32 exhibited detailed replicate-3 data of four different musical sounds treated and control plant group respectively. Table 7.33 depicts the average growth of four music treated and untreated control *Cicer arietinum* plants measured after 48, 96, 144, 192, 240, 288, and 336 hours. The table indicates that all the music treated plants showed better results than control plants except Epic Horror music treated plants. From the beginning to the end of the experiment, Indian Classical music treated plants exhibited maximum plant growth followed by Natural music, and Contemporary music treated plants. The case with Epic Horror music was completely different. This plant group showed lower growth than control up to 240 hours. But 288 hour onwards slightly greater growth was observed than the control plants.

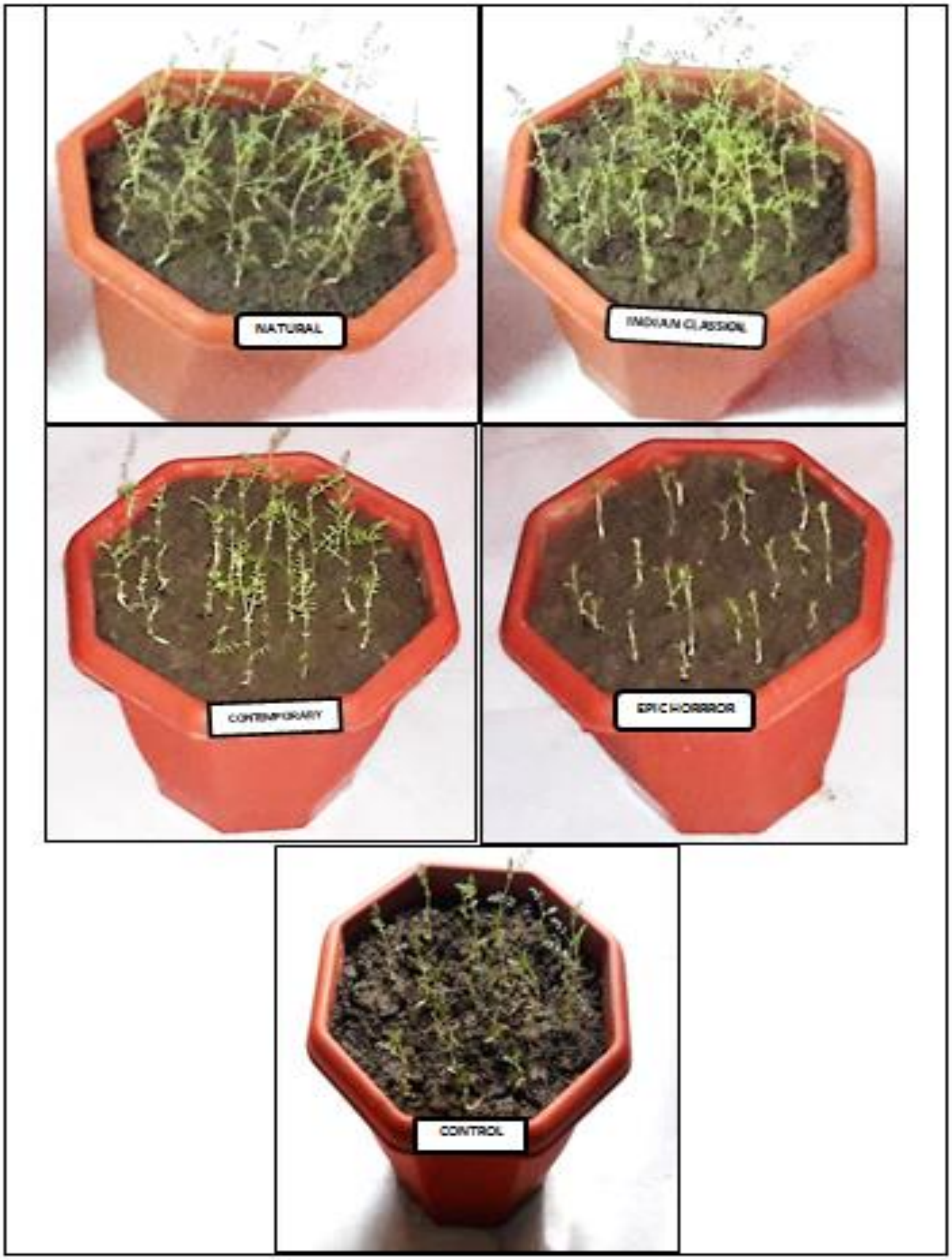


Fig.7.5: Photograph of control and different music treated *Cicer arietinum* plants after 96 hours (Replicate 1)

Replicate-1

Table 7.18: Indian Classical music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.4	7.1	14.2	20.5	25.6	30.5	35.5
2	3.5	7.2	14.3	20.4	25.6	30.6	35.5
3	3.5	7.3	14.2	20.4	25.5	30.6	35.6
4	3.4	7.1	14.3	20.5	25.5	30.6	35.7
5	3.4	7.1	14.2	20.4	25.5	30.5	35.5
6	3.4	7.2	14.2	20.4	25.5	30.6	35.7
7	3.5	7.1	14.3	20.5	25.6	30.6	35.6
8	3.5	7.2	14.3	20.6	25.7	30.6	35.5
9	3.6	7.3	14.4	20.6	25.7	30.5	35.6
10	3.5	7.2	14.4	20.6	25.6	30.5	35.6
11	3.5	7.3	14.4	20.6	25.7	30.6	35.7
12	3.4	7.1	14.3	20.5	25.7	30.7	35.7
13	3.4	7.1	14.3	20.4	25.6	30.5	35.7
14	3.6	7.3	14.5	20.5	25.7	30.6	35.6
15	3.6	7.3	14.4	20.6	25.7	30.6	35.7
16	3.5	7.2	14.4	20.6	25.7	30.6	35.6
17	3.4	7.1	14.2	20.5	25.7	30.7	35.7
18	3.5	7.3	14.4	20.6	25.7	30.7	35.6
19	3.4	7.1	14.4	20.6	25.6	30.7	35.5
20	3.4	7.1	14.3	20.5	25.7	30.7	35.7
Sum	69.4	142.1	286.4	410.3	512.6	612.0	712.3
Mean±SD	3.47±0.07	7.105±0.08	14.32±0.08	20.51±0.07	25.63±0.07	30.6±0.07	35.61±0.07

Replicate-1

Table 7.19: Natural music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.1	6.6	13.0	18.9	25.0	28.8	32.9
2	3.1	6.5	12.9	18.8	24.8	29.0	32.9
3	3.0	6.4	12.9	19.0	24.9	29.0	33.0
4	3.0	6.4	12.8	19.0	25.0	29.0	33.0
5	3.2	6.6	12.9	18.9	25.0	28.9	33.0
6	3.2	6.5	13.0	19.0	25.0	29.0	33.1
7	3.1	6.4	12.8	18.8	24.9	28.9	32.9
8	3.1	6.4	12.9	18.8	24.8	28.9	32.8
9	3.1	6.5	13.0	18.9	24.8	28.8	32.8
10	3.1	6.4	12.9	19.0	25.0	28.9	33.0
11	3.2	6.4	12.8	19.0	24.9	29.0	33.0
12	3.0	6.3	12.9	19.0	24.9	29.0	32.9
13	3.2	6.5	12.9	18.9	24.8	28.8	32.8
14	3.2	6.6	13.0	19.0	25.0	29.0	33.0
15	3.1	6.4	13.0	18.9	25.0	28.8	32.8
16	3.0	6.4	12.9	18.8	24.9	28.8	32.8
17	3.0	6.4	12.9	18.9	24.9	28.9	32.8
18	3.2	6.5	13.0	19.1	25.0	29.0	32.9
19	3.1	6.4	12.8	18.9	25.0	29.0	33.0
20	3.1	6.5	13.0	19.1	25.0	29.0	32.9
Sum	62.1	129.1	258.3	378.7	498.6	578.5	658.3
Mean±SD	3.10±0.07	6.45±0.08	12.91±0.07	18.93±0.09	24.93±0.07	28.92±0.08	32.91±0.09

Replicate-1

Table 7.20: Contemporary music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48	96	144	192	240	288	336
1	2.8	5.7	11.2	17.0	21.5	25.9	30.1
2	2.7	5.6	11.2	17.1	21.5	25.8	29.9
3	2.7	5.6	11.3	17.2	21.6	26.0	30.1
4	2.8	5.6	11.3	17.2	21.5	26.0	29.9
5	2.7	5.5	11.2	17.1	21.5	25.9	30.0
6	2.8	5.6	11.3	17.3	21.6	26.0	30.1
7	2.7	5.6	11.2	17.0	21.4	25.8	30.0
8	2.8	5.6	11.2	17.2	21.5	25.8	29.9
9	2.9	5.7	11.4	17.3	21.5	26.0	30.0
10	2.8	5.7	11.4	17.3	21.6	26.0	30.1
11	2.7	5.6	11.2	17.1	21.5	25.9	30.0
12	2.7	5.5	11.2	17.2	21.6	26.0	30.1
13	2.8	5.6	11.2	17.0	21.4	25.8	30.0
14	2.7	5.6	11.2	17.0	21.5	25.9	30.0
15	2.8	5.7	11.3	17.2	21.6	26.0	30.1
16	2.7	5.5	11.2	17.2	21.6	25.9	30.0
17	2.8	5.6	11.2	17.1	21.4	25.8	29.9
18	2.9	5.7	11.4	17.2	21.5	25.8	29.9
19	2.8	5.6	11.2	17.2	21.4	25.8	29.9
20	2.8	5.6	11.2	17.2	21.5	25.9	30.0
Sum	55.4	112.2	225.0	343.1	430.2	518.0	600.0
Mean±SD	2.77±0.06	5.61±0.06	11.25±0.07	17.15±0.09	21.51±0.07	25.9±0.08	30±0.07

Replicate-1

Table 7.21: Epic Horror music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.2	2.5	5.5	11.6	16.7	21.5	25.4
2	1.1	2.3	5.4	11.4	16.7	21.6	25.4
3	1.1	2.3	5.3	11.4	16.5	21.6	25.5
4	1.2	2.4	5.4	11.5	16.5	21.5	25.5
5	1.2	2.4	5.4	11.6	16.6	21.5	25.5
6	1.1	2.3	5.3	11.5	16.6	21.6	25.6
7	1.2	2.5	5.4	11.6	16.7	21.6	25.6
8	1.2	2.5	5.4	11.5	16.5	21.6	25.5
9	1.2	2.4	5.3	11.3	16.5	21.6	25.5
10	1.1	2.3	5.3	11.5	16.5	21.7	25.6
11	1.1	2.2	5.3	11.5	16.6	21.7	25.5
12	1.2	2.4	5.5	11.5	16.7	21.7	25.5
13	1.2	2.4	5.4	11.6	16.7	21.6	25.6
14	1.1	2.3	5.4	11.5	16.7	21.7	25.6
15	1.2	2.5	5.4	11.4	16.6	21.7	25.6
16	1.1	2.4	5.4	11.5	16.5	21.5	25.4
17	1.2	2.4	5.3	11.5	16.6	21.6	25.5
18	1.2	2.5	5.5	11.5	16.5	21.5	25.5
19	1.3	2.6	5.5	11.6	16.6	21.5	25.5
20	1.2	2.4	5.5	11.6	16.7	21.6	25.6
Sum	23.4	48.0	107.9	230.1	332.0	431.9	510.4
Mean±SD	1.17±0.05	2.4±0.09	5.39±0.07	11.50±0.08	16.6±0.08	21.59±0.07	25.52±0.06

Replicate-1

Table 7.22: *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours without any music stimuli

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.2	4.1	7.9	12.8	16.9	21.0	25.1
2	2.3	4.1	8.0	12.9	17.0	21.1	25.1
3	2.1	4.0	7.8	12.8	17.0	21.2	25.3
4	2.2	4.2	7.9	12.9	17.0	21.1	25.1
5	2.2	4.1	8.0	12.9	17.0	21.1	25.1
6	2.3	4.2	8.0	12.9	16.9	21.0	25.1
7	2.3	4.2	7.9	12.9	16.9	21.0	25.2
8	2.2	4.1	7.9	12.8	16.8	21.0	25.2
9	2.3	4.1	7.9	12.9	16.8	21.0	25.3
10	2.1	4.0	8.0	12.9	17.0	21.2	25.3
11	2.1	4.0	8.0	13.0	17.0	21.2	25.3
12	2.2	4.1	7.9	13.0	17.0	21.1	25.2
13	2.3	4.2	7.9	12.8	16.9	21.1	25.3
14	2.3	4.2	8.0	12.8	16.8	21.0	25.2
15	2.2	4.2	8.0	12.9	17.0	21.1	25.2
16	2.2	4.2	7.9	12.9	17.0	21.2	25.1
17	2.3	4.3	8.0	12.8	16.9	21.0	25.1
18	2.2	4.2	7.9	12.8	16.9	21.1	25.3
19	2.3	4.2	7.9	12.8	16.9	21.1	25.3
20	2.2	4.3	8.0	12.8	16.8	21.0	25.2
Sum	44.5	83.0	158.8	257.3	338.5	421.6	504.0
Mean±SD	2.22±0.06	4.15±0.08	7.94±0.05	12.86±0.06	16.925±0.07	21.08±0.07	25.2±0.08

Replicate-2

Table 7.23: Indian Classical music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.3	7.0	14.1	20.2	25.0	30.1	35.0
2	3.4	7.0	14.1	20.0	25.2	30.3	35.0
3	3.4	7.1	14.1	20.0	25.1	30.2	35.1
4	3.4	7.1	14.1	20.1	25.3	30.2	35.2
5	3.4	7.1	14.0	20.1	25.2	30.2	35.2
6	3.4	7.0	14.2	20.1	25.3	30.3	35.2
7	3.3	7.0	14.0	20.1	25.1	30.2	35.3
8	3.5	7.2	14.2	20.1	25.2	30.3	35.3
9	3.4	7.1	14.1	20.1	25.0	30.1	35.2
10	3.4	7.0	14.0	20.2	25.3	30.2	35.2
11	3.5	7.1	14.2	20.2	25.3	30.3	35.2
12	3.5	7.2	14.2	20.3	25.3	30.1	35.1
13	3.4	7.0	14.0	20.0	25.2	30.2	35.2
14	3.5	7.1	14.1	20.2	25.2	30.3	35.3
15	3.4	7.1	14.2	20.2	25.1	30.1	35.1
16	3.5	7.1	14.0	20.2	25.2	30.2	35.2
17	3.4	7.0	14.1	20.3	25.2	30.3	35.3
18	3.4	7.0	14.0	20.2	25.3	30.3	35.3
19	3.4	7.1	14.2	20.3	25.2	30.3	35.3
20	3.3	7.0	14.1	20.3	25.1	30.4	35.3
Sum	68.2	141.3	282.0	403.2	503.8	604.6	704.0
Mean±SD	3.41±0.06	7.06±0.06	14.1±0.07	20.16±0.09	25.19±0.09	30.23±0.08	35.2±0.09

Replicate-2

Table 7.24: Natural music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.0	6.2	12.6	18.5	24.5	28.6	32.8
2	3.1	6.3	12.6	18.6	24.5	28.5	32.6
3	3.0	6.3	12.7	18.7	24.6	28.5	32.6
4	3.0	6.2	12.6	18.8	24.7	28.6	32.6
5	3.1	6.4	12.8	18.7	24.7	28.8	32.7
6	3.1	6.3	12.6	18.6	24.7	28.7	32.7
7	3.0	6.3	12.7	18.7	24.8	28.8	32.8
8	3.1	6.3	12.7	18.8	24.8	28.7	32.8
9	3.1	6.4	12.8	18.8	24.8	28.8	32.8
10	3.0	6.3	12.7	18.6	24.8	28.7	32.7
11	3.2	6.2	12.6	18.6	24.7	28.6	32.7
12	3.0	6.3	12.8	18.7	24.7	28.6	32.7
13	3.1	6.2	12.6	18.8	24.7	28.8	32.8
14	3.1	6.4	12.8	18.7	24.6	28.7	32.8
15	3.0	6.2	12.5	18.6	24.6	28.6	32.7
16	3.0	6.3	12.6	18.7	24.7	28.8	32.8
17	3.0	6.3	12.6	18.7	24.6	28.6	32.7
18	3.0	6.3	12.8	18.8	24.7	28.7	32.7
19	3.1	6.4	12.8	18.7	24.7	28.7	32.7
20	3.1	6.4	12.8	18.8	24.6	28.6	32.6
Sum	61.1	126.0	253.7	373.9	493.5	573.4	654.3
Mean±SD	3.05±0.05	6.3±0.07	12.68±0.09	18.69±0.08	24.67±0.08	28.67±0.09	32.71±0.07

Replicate-2

Table 7.25: Contemporary music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48	96	144	192	240	288	336
1	2.6	5.5	11.1	17.1	21.4	25.9	30.0
2	2.6	5.4	11.0	17.1	21.5	26.0	30.0
3	2.7	5.6	11.3	17.2	21.6	26.0	30.1
4	2.6	5.5	11.1	17.2	21.5	26.0	30.0
5	2.7	5.6	11.2	17.2	21.5	26.0	30.0
6	2.6	5.4	11.1	17.0	21.4	25.9	29.9
7	2.6	5.5	11.1	17.0	21.4	25.8	29.9
8	2.7	5.6	11.2	17.2	21.6	26.0	29.9
9	2.6	5.5	11.1	17.0	21.4	25.8	30.0
10	2.6	5.4	11.0	17.1	21.4	25.8	30.0
11	2.6	5.5	11.2	17.1	21.5	25.9	30.0
12	2.6	5.6	11.2	17.1	21.6	26.0	30.0
13	2.6	5.6	11.2	17.1	21.4	25.8	30.1
14	2.7	5.6	11.1	17.0	21.4	25.9	30.0
15	2.7	5.6	11.3	17.2	21.6	26.0	30.1
16	2.6	5.5	11.2	17.2	21.6	25.9	30.0
17	2.7	5.6	11.3	17.2	21.5	25.8	29.9
18	2.6	5.5	11.2	17.2	21.5	25.9	30.0
19	2.6	5.5	11.1	17.2	21.5	25.9	29.9
20	2.7	5.6	11.3	17.1	21.5	25.8	30.0
Sum	52.7	110.6	223.3	342.5	429.8	518.1	599.8
Mean±SD	2.63±0.04	5.53±0.07	11.16±0.09	17.12±0.07	21.49±0.07	25.90±0.08	29.99±0.06

Replicate-2

Table 7.26: Epic Horror music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.1	2.4	5.4	11.4	16.5	21.5	25.5
2	1.3	2.4	5.4	11.4	16.6	21.6	25.5
3	1.3	2.6	5.5	11.3	16.5	21.5	25.5
4	1.2	2.4	5.6	11.5	16.6	21.5	25.4
5	1.1	2.4	5.5	11.5	16.6	21.5	25.4
6	1.1	2.4	5.3	11.4	16.6	21.5	25.6
7	1.2	2.4	5.4	11.5	16.6	21.6	25.6
8	1.3	2.4	5.4	11.4	16.6	21.6	25.6
9	1.2	2.5	5.3	11.3	16.4	21.5	25.5
10	1.3	2.5	5.5	11.5	16.5	21.5	25.5
11	1.2	2.4	5.4	11.4	16.4	21.4	25.4
12	1.3	2.6	5.5	11.5	16.6	21.5	25.5
13	1.2	2.5	5.4	11.5	16.5	21.5	25.4
14	1.1	2.3	5.4	11.5	16.5	21.4	25.6
15	1.2	2.5	5.5	11.5	16.4	21.4	25.5
16	1.3	2.6	5.4	11.5	16.5	21.5	25.4
17	1.2	2.4	5.4	11.5	16.4	21.4	25.5
18	1.2	2.5	5.5	11.5	16.5	21.5	25.6
19	1.1	2.4	5.5	11.4	16.5	21.4	25.5
20	1.2	2.4	5.6	11.5	16.5	21.6	25.5
Sum	24.1	49.0	108.9	229.0	330.3	429.9	510.0
Mean±SD	1.20±0.07	2.45±0.08	5.44±0.08	11.45±0.06	16.51±0.07	21.49±0.06	25.5±0.07

Replicate-2

Table 7.27: *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours without any music stimuli

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.1	4.1	7.8	12.9	17.0	21.2	25.3
2	2.0	4.1	7.9	12.9	17.1	21.2	25.2
3	2.1	4.1	7.9	12.8	16.9	21.0	25.1
4	2.2	4.2	7.9	12.8	16.9	21.1	25.3
5	2.0	4.2	7.9	12.9	16.9	21.1	25.2
6	2.1	4.2	7.9	12.9	17.0	21.1	25.3
7	2.1	4.1	7.8	12.8	16.9	21.0	25.1
8	2.2	4.3	8.0	12.8	16.8	21.0	25.2
9	2.0	4.1	7.9	12.8	16.8	21.0	25.1
10	2.2	4.3	8.0	12.9	17.0	21.2	25.3
11	2.1	4.3	8.0	13.0	17.0	21.2	25.3
12	2.1	4.2	7.9	13.0	17.0	21.1	25.2
13	2.2	4.3	7.9	12.8	16.9	21.0	25.2
14	2.0	4.2	8.0	12.9	16.9	21.0	25.2
15	2.2	4.1	7.9	12.9	17.0	21.1	25.2
16	2.1	4.3	8.0	12.9	17.0	21.2	25.1
17	2.1	4.2	8.0	12.8	16.9	21.0	25.2
18	2.1	4.1	7.9	12.9	17.0	21.1	25.3
19	2.2	4.1	7.9	13.0	17.1	21.2	25.3
20	2.2	4.3	8.0	12.8	17.0	21.2	25.2
.Sum	42.3	83.8	158.5	257.5	339.1	422.0	504.3
Mean±SD	2.11±0.07	4.19±0.08	7.92±0.06	12.87±0.06	16.95±0.08	21.1±0.08	25.21±0.07

Replicate-3

Table 7.28: Indian Classical music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Indian Classical							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.5	7.4	14.7	20.8	25.9	31.0	35.9
2	3.6	7.4	14.8	20.8	25.8	31.0	36.0
3	3.7	7.6	14.9	20.8	25.9	30.8	35.7
4	3.7	7.6	14.8	20.9	25.9	30.8	35.8
5	3.6	7.5	14.8	21.0	25.9	30.9	35.8
6	3.6	7.5	14.9	21.0	26.0	30.9	36.0
7	3.5	7.4	14.9	20.9	26.0	30.9	35.9
8	3.6	7.4	14.8	20.9	25.9	31.0	36.0
9	3.5	7.5	14.9	20.9	25.9	31.0	35.9
10	3.6	7.5	14.9	20.8	25.9	30.9	35.9
11	3.6	7.5	14.9	20.8	25.8	30.9	35.8
12	3.6	7.6	14.9	20.9	25.8	30.8	35.8
13	3.7	7.6	15.0	20.9	25.8	30.8	35.9
14	3.7	7.6	14.9	21.0	25.9	30.8	35.9
15	3.6	7.4	14.8	20.9	26.0	30.9	36.0
16	3.5	7.4	14.7	20.9	26.0	30.9	36.0
17	3.5	7.5	14.8	20.9	26.0	31.0	35.9
18	3.5	7.4	14.9	20.9	25.9	30.9	35.9
19	3.6	7.6	15.0	20.9	26.0	31.0	35.8
20	3.7	7.7	15.0	21.0	25.9	30.9	35.9
Sum	71.9	150.1	297.3	417.9	518.2	618.1	717.8
Mean±SD	3.59±0.07	7.50±0.09	14.86±0.08	20.89±0.06	25.91±0.07	30.90±0.07	35.89±0.08

<u>Replicate-3</u>

Table 7.29: Natural music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Natural							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	3.2	6.6	13.0	18.8	24.8	28.8	32.7
2	3.1	6.4	13.0	19.0	24.8	28.8	32.8
3	3.2	6.6	12.9	19.0	25.0	28.9	32.9
4	3.1	6.4	12.9	18.9	25.0	29.0	33.0
5	3.1	6.5	13.0	18.9	25.0	28.9	33.0
6	3.2	6.6	13.0	19.0	24.9	29.0	33.0
7	3.3	6.6	13.0	18.8	24.9	29.0	32.9
8	3.2	6.6	13.0	18.9	24.9	28.9	32.9
9	3.1	6.4	13.0	18.9	24.8	28.9	32.9
10	3.2	6.6	13.0	19.1	25.0	29.0	33.0
11	3.2	6.6	13.0	18.8	24.9	29.0	32.9
12	3.3	6.7	13.0	19.0	25.0	29.0	32.9
13	3.1	6.5	12.9	18.9	24.8	28.8	32.8
14	3.2	6.6	13.0	19.0	25.0	29.0	33.0
15	3.1	6.4	12.8	18.9	25.0	28.9	33.0
16	3.2	6.5	13.0	18.9	25.0	28.8	32.8
17	3.1	6.4	12.9	18.9	24.9	28.9	33.0
18	3.2	6.5	13.0	19.0	25.0	29.0	33.0
19	3.2	6.4	12.8	18.9	24.9	29.0	33.0
20	3.1	6.5	13.0	19.0	25.0	28.9	32.9
Sum	63.4	130.4	259.2	378.6	498.6	578.5	658.4
Mean±SD	3.17±0.06	6.52±0.09	12.96±0.06	18.93±0.07	24.93±0.07	28.925±0.07	32.92±0.08

Replicate-3

Table 7.30: Contemporary music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Contemporary							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48	96	144	192	240	288	336
1	2.9	5.8	11.3	17.3	21.6	26.0	30.1
2	2.8	5.8	11.4	17.2	21.6	26.1	30.0
3	2.8	5.7	11.3	17.2	21.6	26.0	30.1
4	2.8	5.6	11.2	17.2	21.5	25.9	30.0
5	2.7	5.6	11.3	17.2	21.5	26.0	30.0
6	2.8	5.6	11.3	17.3	21.7	26.1	30.1
7	2.9	5.8	11.4	17.2	21.6	26.0	30.0
8	2.8	5.7	11.3	17.3	21.7	26.0	30.1
9	2.9	5.8	11.4	17.4	21.7	26.1	30.1
10	2.9	5.7	11.3	17.3	21.6	26.0	30.1
11	2.8	5.6	11.2	17.1	21.5	26.0	30.0
12	2.8	5.7	11.3	17.2	21.6	26.0	30.1
13	2.7	5.6	11.2	17.0	21.4	25.9	30.0
14	2.8	5.6	11.3	17.3	21.7	26.1	30.0
15	2.8	5.7	11.3	17.2	21.6	26.0	30.1
16	2.8	5.8	11.4	17.4	21.7	26.1	30.0
17	2.8	5.7	11.2	17.3	21.7	26.1	30.2
18	2.9	5.8	11.4	17.2	21.6	26.0	30.0
19	2.8	5.8	11.4	17.3	21.7	26.1	30.2
20	2.7	5.6	11.3	17.2	21.6	26.1	30.2
Sum	56.2	114.0	226.2	344.8	432.2	520.6	601.4
Mean±SD	2.81±0.06	5.7±0.08	11.31±0.07	17.24±0.09	21.61±0.08	26.03±0.06	30.07±0.07

Replicate-3

Table 7.31: Epic Horror music treated *Cicer arietinum* plant growth in terms of stem length in cm. with time in hours

Music stimuli – Epic Horror							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	1.5	2.8	5.7	11.7	16.9	21.8	25.8
2	1.5	2.9	5.7	11.6	16.7	21.7	25.8
3	1.4	2.8	5.8	11.8	16.9	21.9	25.8
4	1.5	2.8	5.8	11.7	16.8	21.8	25.9
5	1.4	2.8	5.7	11.7	16.9	21.9	25.9
6	1.4	2.9	5.8	11.8	16.9	21.8	25.8
7	1.5	2.8	5.8	11.7	16.9	21.9	25.9
8	1.3	2.7	5.6	11.6	16.8	21.8	25.7
9	1.5	2.9	5.8	11.7	16.8	21.7	25.7
10	1.5	2.9	5.8	11.7	16.8	21.8	25.8
11	1.5	2.8	5.8	11.8	16.9	21.9	25.8
12	1.3	2.7	5.7	11.7	16.9	21.8	25.9
13	1.5	2.9	5.7	11.8	16.9	21.8	25.9
14	1.4	2.8	5.6	11.5	16.7	21.7	25.8
15	1.4	2.8	5.7	11.6	16.8	21.7	25.7
16	1.4	2.9	5.7	11.5	16.7	21.7	25.8
17	1.3	2.7	5.6	11.7	16.9	21.8	25.9
18	1.3	2.8	5.6	11.6	16.8	21.7	25.8
19	1.4	2.8	5.7	11.7	16.9	21.9	25.8
20	1.4	2.8	5.7	11.7	16.8	21.7	25.7
Sum	28.4	56.3	114.3	233.6	336.7	435.8	516.2
Mean±SD	1.42±0.07	2.81±0.06	5.71±0.07	11.68±0.08	16.83±0.07	21.79±0.07	25.81±0.07

Replicate-3

Table 7.32: ***Cicer arietinum*** **plant growth in terms of stem length in cm. with time in hours without any music stimuli**

Control group							
Growth in terms of stem length in cm. with time in hours							
Sample No.	48 hours	96 hours	144 hours	192 hours	240 hours	288 hours	336 hours
1	2.3	4.2	7.9	12.9	16.9	21.0	25.2
2	2.4	4.4	8.0	13.0	17.0	21.2	25.3
3	2.3	4.3	8.0	12.9	17.0	21.2	25.3
4	2.2	4.2	7.9	13.0	17.0	21.2	25.4
5	2.3	4.2	8.0	12.9	17.0	21.1	25.3
6	2.4	4.3	8.0	13.0	16.9	21.0	25.2
7	2.4	4.4	8.0	13.0	17.0	21.1	25.4
8	2.3	4.3	8.0	13.0	16.9	21.0	25.2
9	2.2	4.3	8.0	12.9	16.9	21.2	25.3
10	2.3	4.3	8.0	13.0	17.1	21.2	25.4
11	2.2	4.3	8.0	13.0	17.0	21.2	25.3
12	2.3	4.4	8.0	13.0	17.1	21.3	25.4
13	2.4	4.4	8.1	13.0	16.9	21.0	25.3
14	2.3	4.3	8.0	12.9	16.9	21.0	25.3
15	2.3	4.2	8.0	13.0	17.0	21.1	25.4
16	2.4	4.4	8.1	13.1	17.1	21.2	25.4
17	2.3	4.4	8.1	12.9	16.9	21.0	25.3
18	2.3	4.2	7.9	12.8	16.9	21.1	25.4
19	2.4	4.3	8.0	12.9	17.0	21.1	25.3
20	2.4	4.4	8.1	13.1	17.1	21.3	25.5
Sum	46.4	86.2	160.1	259.3	339.6	422.5	506.6
Mean±SD	2.32±0.06	4.31±0.07	8.00±0.05	12.96±0.07	16.98±0.07	21.12±0.09	25.33±0.07

Table 7.33: *Cicer arietinum* plant growth (stem length in cm) with time (in hours) averaged over all the replicates

	Control	Indian Classical music	Natural music	Contemporary music	Epic Horror music
48 hours	2.2±0.11	3.4±0.1	3.1±0.08	2.7±0.09	1.2±0.13
96 hours	4.2±0.1	7.2±0.2	6.4±0.12	5.6±0.1	2.5±0.2
144 hours	7.9±0.06	14.4±0.33	12.8±0.14	11.2±0.09	5.5±0.16
192 hours	12.9±0.08	20.5±0.31	18.8±0.14	17.1±0.1	11.5±0.12
240 hours	16.9±0.08	25.5±0.3	24.8±0.14	21.5±0.09	16.6±0.15
288 hours	21.1±0.08	30.5±0.28	28.8±0.14	25.9±0.09	21.6±0.14
336 hours	25.2±0.09	35.5±0.29	32.8±0.12	30.02±0.07	25.6±0.15

Figure 7.6 has drawn from the Table 7.33 to make the result more perceivable. Figure 7.7 depicts the average plant growth differences (in percentage) of four music treated plants relative to the untreated control plants after 48, 96, 144, 192, 240, 288, and 336 hour. At the end of the experiment, the average stem length of *Cicer arietinum* exposed to Indian Classical music, Natural music, Contemporary music, and Epic Horror music was 40.8%, 30.1%, 19.1% and 1.5% greater relative to the untreated control plants.

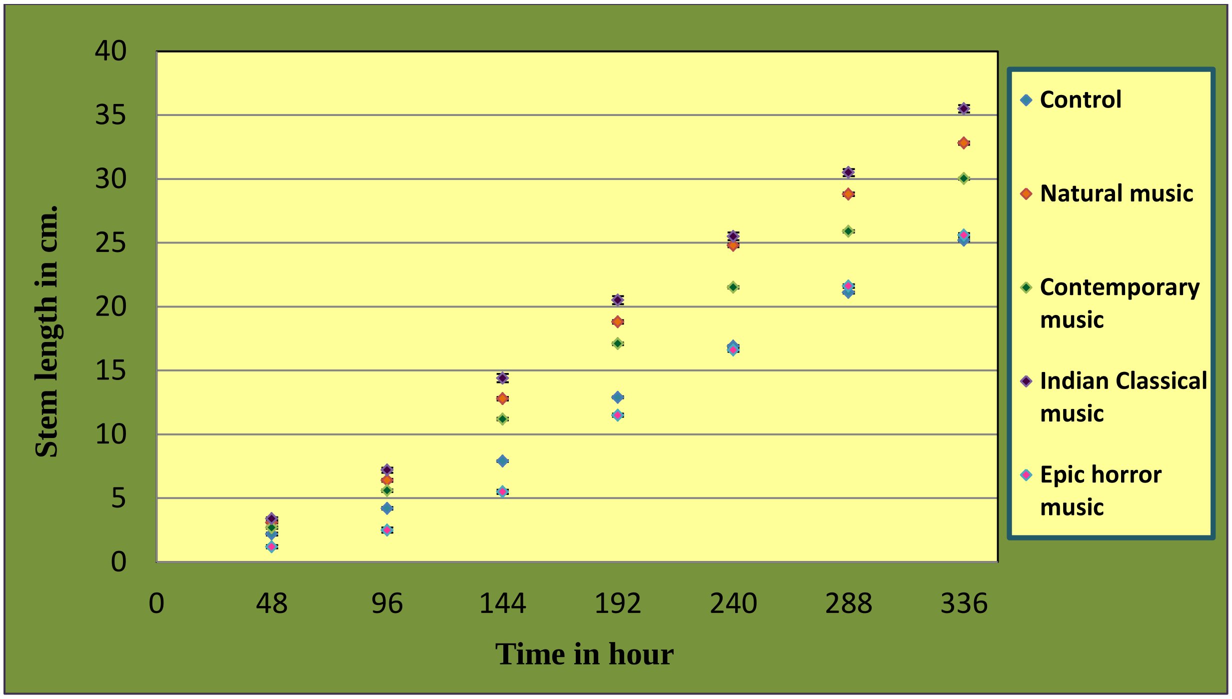


Fig.7.6: Graph showing average stem length of control and different music treated *Cicer arietinum* plants versus time (Vertical bars represent mean ± SD)

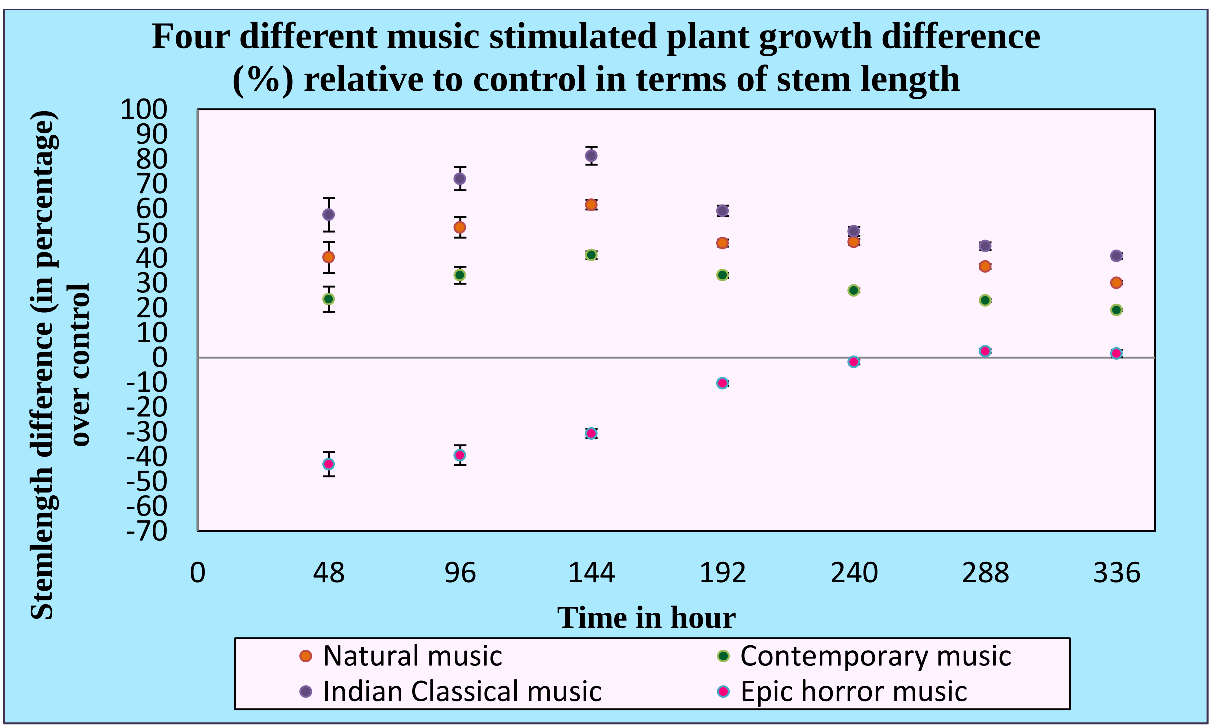


Fig.7.7: Graph showing differences in average stem length (percentage) of four different musical sound treated *Cicer arietinum* plants relative to control versus time (Vertical bars represent mean ± SD)

7.3.3 EFFECT OF DFA SCALING EXPONENTS ON *Pisum sativum* and *Cicer arietinum* PLANT GROWTH

The above results imply that growth of *Pisum sativum* and *Cicer arietinum* were affected by musical sound of distinct types. Significant differences have been observed in stem lengths among the control and different musical stimuli exposed (Indian Classical music, Natural music, Contemporary music, and Epic horror music) plants after specific time intervals. Throughout the experimental period the average growth regarding stem length of all the music treated plants were much higher when compared to the untreated control except Epic horror music stimulated plants. Fig.7.8 and Fig.7.9 depicts the relationship between final growth difference (in %) of four different music stimuli exposed *Pisum sativum* and *Cicer arietinum* plants relative to control and corresponding DFA scaling exponent values of music signals. At the end of the experiment, the Indian Classical music with mean DFA exponent value of 1.683 showed the highest growth in pea and gram plants than untreated control plants followed by Natural music and Contemporary music with DFA value of 1.388 and 0.778 respectively. With mean DFA exponent value of 0.217 the Epic horror music exhibited decreased plant growth in pea plants up to 288 hour when compared to control but finally after 336 hour the growth was slightly higher than untreated control group. Among the music treated pea plants, the highest growth was noted after 144 hour for Indian Classical music, Natural music, and Contemporary music treated plants and the lowest increased growth was noted after 336 hour for Epic Horror music stimulated plants when compared to the untreated control plants. The plants of all the triplicates showed the same trend of growth pattern in *Pisum sativum*. In *Cicer arietinum* plants, Epic horror music showed decreased growth up to 240 hour than untreated control but 288 hours onward the plants exhibited slightly increased growth than untreated control plant group. Here also, among the music treated

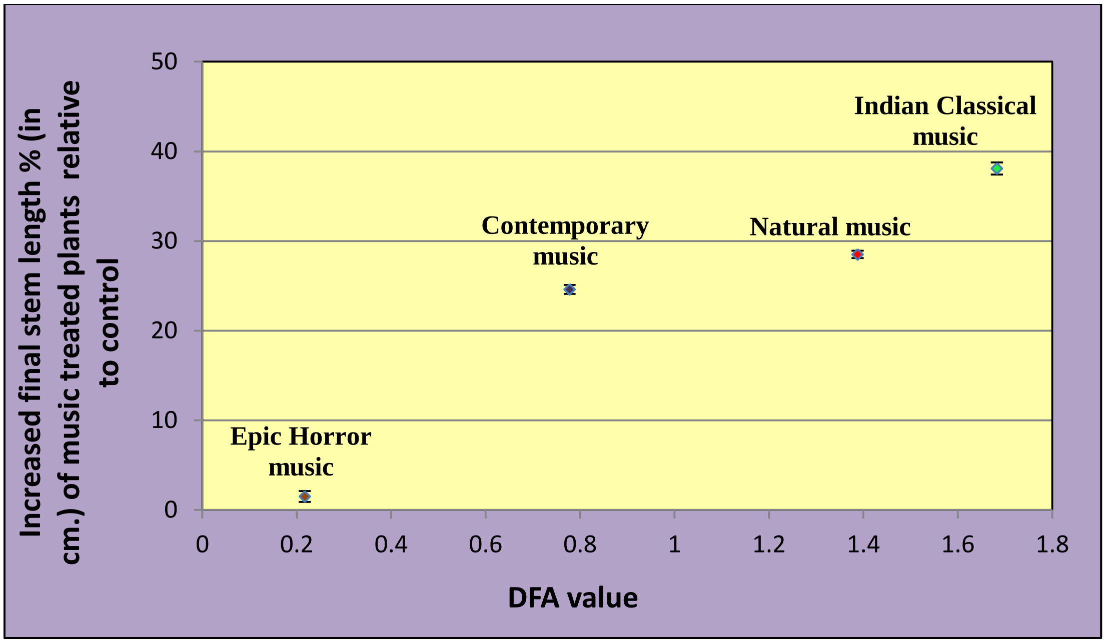


Fig.7.8: Graph depicting the final stem length difference of different music stimulated *Pisum sativum* plants over control versus DFA exponents of four various kinds of music stimuli used as input.

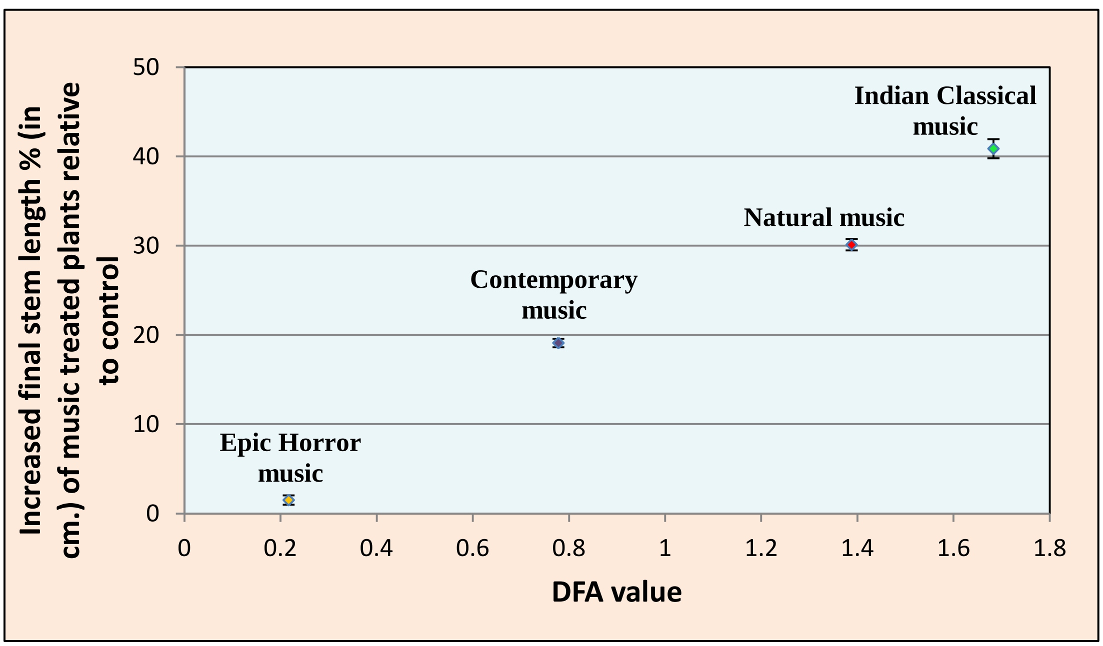


Fig.7.9: Graph depicting the final stem length difference of different music stimulated *Cicer arietinum* plants over control versus DFA exponents of four various kinds of music stimuli used as input.

plants, the maximum increased growth rate was noted after 144 hour at Indian Classical music, Natural music, and Contemporary music treatments and the lowest growth was noted after 288 hour at Epic Horror music treatment when compared to the untreated control plants.It is worth noting in this perspective that in both cases Classical music with highest DFA value manifested best growth result in terms of stem length or height parameter. Further the degree of response of *Pisum sativum* and *Cicer arietinum* plant growth for different types of musical sound is strictly DFA scaling exponent dependent.

7.4 DISCUSSION

The effect of music on plants has received little attention till date. The impact of music on plants from acoustical complexity mainly DFA exponent point of view has hardly ever done by anyone. From the above findings it is evident that musical sound stimuli affect plant growth differently for distinct DFA values. Each genre of music has its very specific pattern of scaling or self-similarity which leads to a complete distinctive pattern in their DFA scaling exponent. Herein lays the originality of that musical clip, each of which creates a completely different mood and ambiance very distinctive from the other, the basics of which are hidden in the complex waveform possessed by each. The clip used for Indian Classical music had the highest order of self- similarity while the clip used for Epic Horror music had the lowest degree of self- similarity. The clips with Natural music and Contemporary music had LRTC which lies somewhere in between the two. In this study we attempted to detect the degree of response of plants (in terms of height) with different types of music conventionally labelled as Indian Classical, Natural, Contemporary, and Epic Horror characterized by specific spectral complexity (DFA scaling exponent). The results clearly depicts that the plant growth mainly stem length in *Pisum sativum* and *Cicer arietinum* depends on DFA scaling exponents of music stimuli and this dependence is very much species specific. It can be concluded that the presence of strong long range correlation in the acoustic feature of music sample may lead to higher response in plant so far as growth is concerned. The response pattern of plants may provide a guideline for further research and shall be helpful for understanding in detail from a deeper scientific footing.

CHAPTER 8

THE IMPACT OF DIFFERENT MUSIC STIMULI ON GROWTH AND STRESS PHYSIOLOGY OF NILE TILAPIA (*Oreochromis niloticus*)

8.1 <u>INTRODUCTION</u>

Under artificial rearing condition, stress acts as a critical factor exerting negative impacts on fish physiology like growth, reproduction, immune function, homeostasis, metabolic and neurohormonal functions (1, 2, 3). It is possible to improve fish welfare providing them a more enriched environment. Environmental enrichment is nothing but modifications of the environment leading towards better biological functions like improved growth, decreased stress etc. The review literatures regarding effects of Musical "auditory" environmental enrichment on fish have already been discussed in chapter 2. Despite having considerable anatomical differences between pieces and human brain; it has been observed that the impact of music on fish brain very closely mirrors the brain of human. Music not only helps fish to relax, but also enable them to attain high levels of homeostasis.

The present study aimed to evaluate the potential effect of different music exposures as auditory enrichment on physiological statuses such as growth and stress state as response measures in Nile tilapia (*Oreochromis niloticus*). Stress was evaluated on the basis of plasma cortisol levels. A further study was also done to establish the relationship between the above mentioned physiological parameters with DFA scaling exponents of music signals.

8.2 <u>EFFECT OF STRESSORS ON FISH PHYSIOLOGY</u>

In captive fisheries, the response to stress is characterized by the stimulation of the hypothalamo–pituitary–adrenal–inter-renal axis, which results in a series of metabolic and physiological changes (4). Under stress condition, three types of responses have mainly been recognized in fishes – primary, secondary and tertiary responses (Fig.8.1). The primary response is the insight of a changed condition by central nervous system (CNS) and release of stress hormone cortisol (5). Cortisol is a major major glucocorticoid having important immune, metabolic and osmoregulatory function in teleost fishes (6). The inter-renal cells sparsely distributed within the head kidney produces cortisol which after secretion released into the blood (7). The plasma cortisol is considered as the only physiologically active form and a reliable indicator of stress in fish. Released cortisol evokes secondary responses (8) inducing alteration in the blood and tissue chemistry,

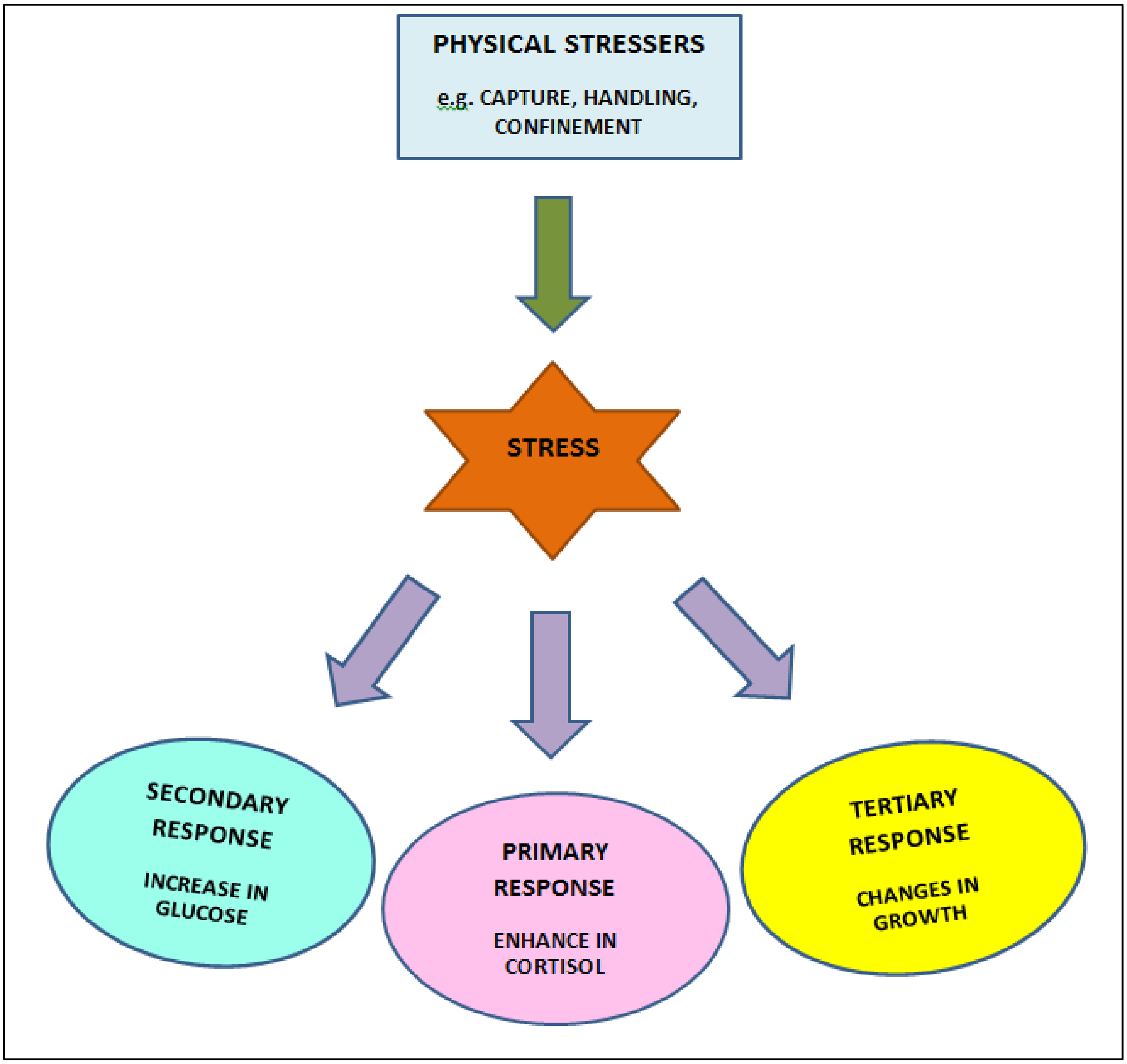


Fig.8.1: Physical stressors act on fish to evoke physiological and related effects, which are grouped as primary, secondary and tertiary (whole-animal) responses

resulting in enhanced plasma glucose level (9, 10). Scientists have showed that fishes undergoing stressful situations exhibit elevated plasma cortisol and glucose levels (11, 12, 13). The secondary responses are responsible for the tertiary responses such as changes in growth, behaviour, metabolic state and ultimately survival (14).

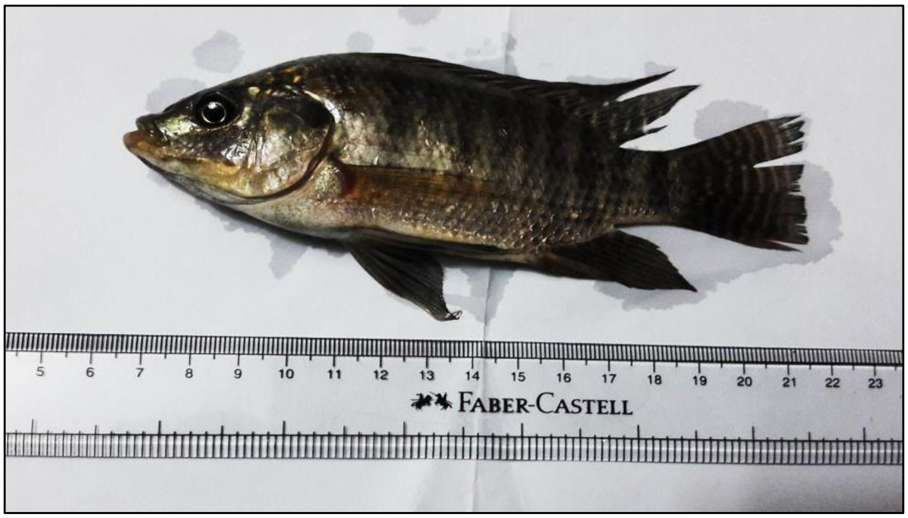
8.3 METHODOLOGY

8.3.1 DETRENDED FLUCTUATION ANALYSIS OF MUSIC SIGNALS

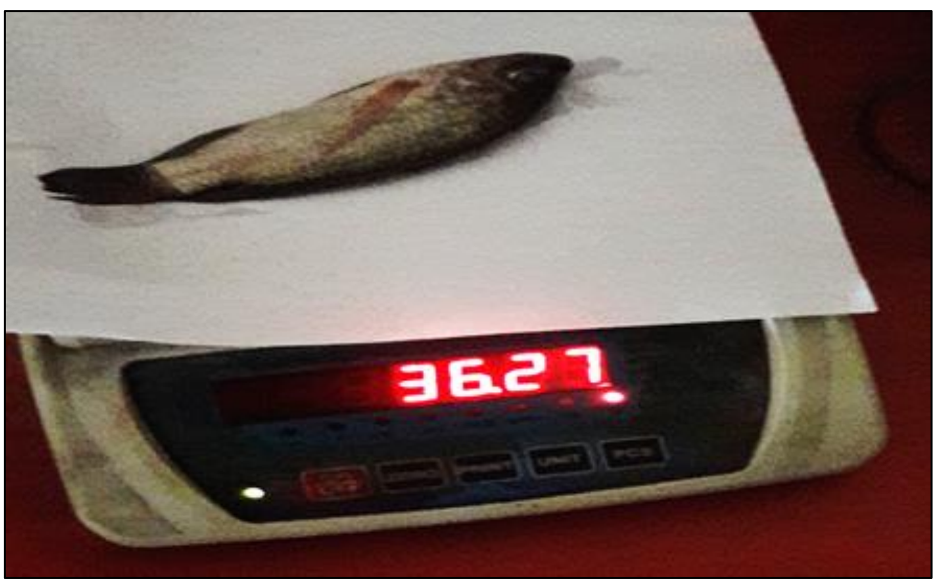
Here, the same Indian Classical music and Contemporary music was used as audio signals to stimulate Nile tilapia that were used in case of plants. The DFA computation follows the method as discussed in chapter 3.

8.3.2 EXPERIMENTAL DESIGN FOR FISH ACCLIMATION AND REARING CONDITIONS

For the present study, healthy Nile tilapias were obtained from a local commercial farm in Kolkata. The experiment was conducted for 45 days in 3 groups- Indian Classical music treated group, Contemporary music treated group and untreated control group.There were 3 replicates for each group. The experimental design followed a completely randomized control design. Initially fish were introduces in aquaria and were left for two weeks to acclimatize in new environment. During this time no music was played. After 2 weeks of acclimatization period, the fish weighing an average of 10.64 ± 0.15 g (means ± standard deviation [SD]) were randomly placed in aquaria with dimensions of 60x35x40 cm^3 and with a density of 15 fish per aquarium. Each aquarium was supplied with an aerator to increase the dissolved oxygen content and an automatic heater to regulate water temperature. The temperature was adjusted at 27 ± 1°C, with dissolved oxygen range of 6.2-6.7 mg/L and water pH range of 7.2-7.5. Dissolved oxygen was measured by iodimetric method and pHwith a pH meter. The photoperiod was regulated as 12 hour light and 12 hour darkness with LED light at water surface. During the experiment, three-fourths of the aquarium's water with fish faeces was siphoned every day before feeding and were replaced by an equal volume of well-aerated water. Fish were removed from the aquaria by net and were measured every 2 weeks and at the end of the experiment (Fig.8.2). To reduce the stress



(A)



(B)

Fig.8.2: Photographs showing Nile Tilapia (A) length and (B) body weight measurements

caused by handling, fish were anesthetized prior weighing. Fish mortality was checked on a regular basis. During the experimental period no fish mortality has occurred. Fish populations were hand fed a commercial pelleted diet (crude protein 56.2%, crude lipid 25.2%, moisture 5.3%, ash 7.8%, fibre and nitrogen-free extract 5.5%), at 3 % body weight, twice daily at 7.30 am and 6.30 pm,7 days a week. During feeding, even distributions of ration within all fish in the aquaria were assured. Feeding continued until satiation when fish became motionless at the bottom of the aquaria and stopped eating. The food quantity was adjusted after every sampling occasion.

8.3.3 EXPERIMENTAL DESIGN FOR EXPOSURE AND UNDER WATER TRANSMISSION OF MUSICAL SOUNDS

In this study, the design and construction of equipments required for music treatments and under water sound transmission has shown schematically in Figure 8.3. Music was played 3 times a day for 2 hours at 8.00, 12.00 and 16.00. During these hours the filtration system was switched off in all the three tanks to eliminate any kind of noise. Two different types of music were played as audio signal to fishes–Indian Classical music and Contemporary music. Aquaria A1, A2, A3 were Indian Classical music treated aquaria for replicate 1, 2, and 3 respectively. Aquaria B1, B2, and B3 had Contemporary music treatment and aquaria C1, C2, C3 were the untreated control aquaria. The pieces of music were repeated during the music treatments. Two music players were equipped with timer controller system to ply and fix the time period of music exposures. For both the music treated aquaria, the music player containing the CD of music was attached to a speaker with a cable and the speaker was placed under water in one corner of the aquarium. An amplifier was utilized after the output of the music player. The amplitude of music was set as 30 decibel. The intensity was measured by a hydrophone. The sound transmittance equipments were monitored every day. The experimental sets were made in such a way that it did not obstruct fish swimming.

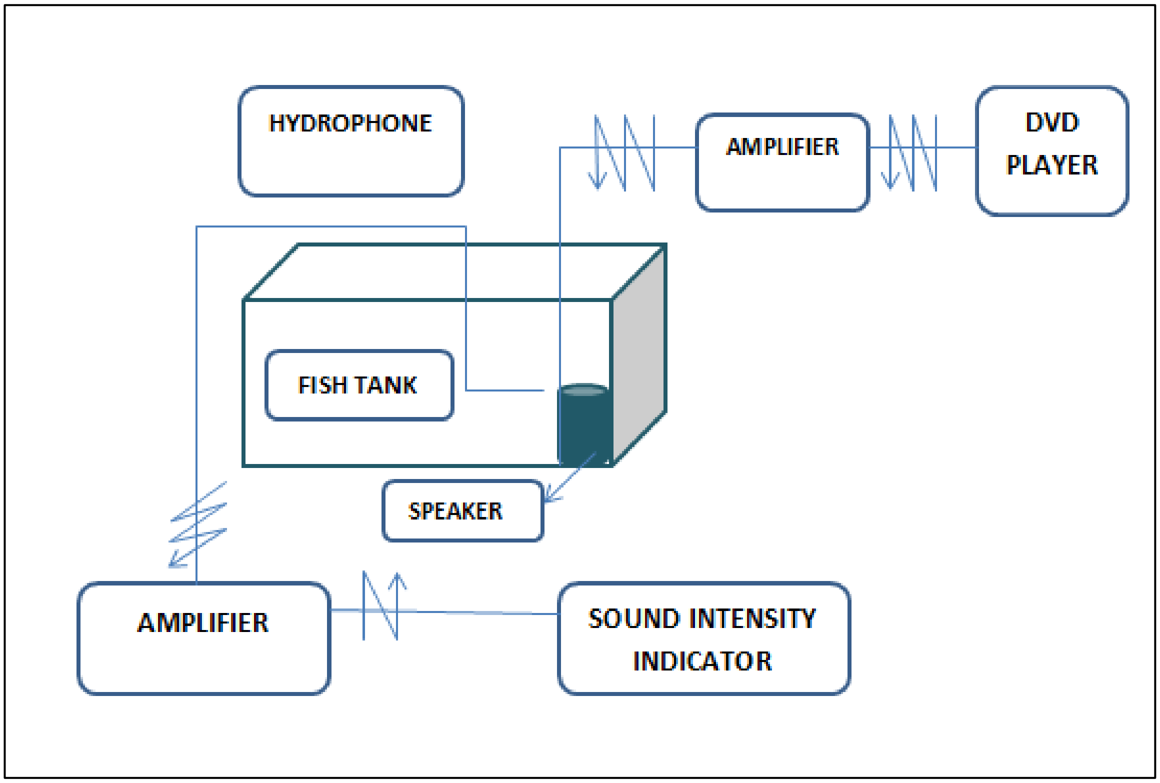


Fig.8.3: Schematic diagram of music transmission in tilapia aquarium with recording of hydrophone output

Control fish were kept in a different room away from the room used for music exposure experimental room. No musical sound was presented to the control groups, and this lack of music exposure during the experiment was the only difference from the music treated experimental fish groups.

8.3.4 MEASUREMENT AND CALCULATION OF GROWTH PARAMETERS

At the end of the experiment, all fish specimens in the aquaria were anesthetized, counted and weighed to calculate fish growth performances including body weight gain, specific growth rate (SGR), and final length gain.The first two response variables were calculated according to Subandiyono & Hastuti, 2016 (15) as follows:

Weight gain (WG %) = 100 × (Wt – W_0) x W_0^{-1}

Specific growth rate (SGR % day^{-1}) = 100 × (Ln Wt - Ln W_0) x T^{-1}

Where:Wt and W_0 - the final fish weight and initial fish weight;

T - the time (days) of fish maintenance, which is 45 days;

Ln: Natural log;

8.3.5 DETERMNATION OF BLOOD PARAMETER

At the end of the experiment, fish were not fed during the 24 hours immediately prior to blood sampling. Five fish were taken randomly from each aquarium and were anesthetized with buffered tricaine methanesulfonate (20 mg/l). Blood was collected from the caudal vasculature using heparinized syringes. Blood samples were transferred to glass test tubes and centrifuged at 3000 rpm for 10 minutes. Plasma was collected with digital micropipette in Eppendorf tubes and stored at -20^{o}C until required for assay. The collected plasma was subjected to determination of cortisol. Plasma cortisol levels (in ng/ml) were measured by ELISA assay.

8.4 <u>RESULTS</u>

8.4.1 DFA SCALING EXPONENTS OF MUSIC SIGNALS

Table 8.1 shows the variation of DFA Scaling Exponents for Indian Classical music and Contemporary music used in this study.

Table 8.1: Variation of DFA scaling exponent for different parts of 2 musical stimuli

	DFA scaling exponent	
	Clip 1 Indian Classical music	**Clip 2Contemporary Music**
Part 1	1.652	0.764
Part 2	1.584	0.812
Part 3	1.815	0.758

8.4.2 GROWTH ANALYSIS

Weight was measured for individual fish at day 1, day 15, day 30 and day 45. Similarly, individual fish length was measured at day 1 and at the end of the experiment. These results were used to derive the weight gain %, specific growth rate % and length gain %. Graphs were drawn from these data to make the results more visible and to interpret easily. Table 8.2, Table 8.3 and Table 8.4 shows the measured weight values of Indian Classical music treated, Contemporary music treated and untreated control fish groups atday 1, day 15, day 30 and day 45 for replicate-1. Table 8.5, Table 8.6 and Table 8.7; and Table 8.8, Table 8.9, Table 8.10 reveals the same for replicate-2 and replicate-3 sequentially. Table 8.11 shows the measured weight values of the above mentioned fish groups averaged over three replicates. Figure 8.4 is the graphical representation of Table 8.11. Table 8.12, Table 8.13, Table 8.14 exhibits the final weight gain % data of two kinds of music treated and untreated fish groups for replicate-1. Table 8.15, Table 8.16, Table 8.17 are the same for replicate-2 and Table 8.18, Table 8.19, Table 8.20 shows the weight gain % data for replicate-3 respectively. Table 8.21 exhibits the calculated weight gain % of the three fish groups together averaged over all the replicates.

Replicate-1

Table 8.2: Measured weight values (in gm.) of Aquarium-A1 fish group at different time intervals

Aquarium-A1 (Indian Classical music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.75	19.02	26.05	36.1
2	10.46	18.94	26.20	35.91
3	10.33	18.56	25.87	35.78
4	10.58	18.97	26.09	35.89
5	10.72	19.10	26.40	36.20
6	10.57	18.88	26.13	36.07
7	10.83	18.99	26.52	37.01
8	10.55	18.85	25.96	35.88
9	10.52	19.05	26.31	36.33
10	10.67	19.24	26.76	36.54
11	10.86	19.13	26.68	36.24
12	10.33	18.56	25.89	35.96
13	10.82	19.24	26.34	36.03
14	10.38	18.68	26.07	35.86
15	10.67	19.09	26.46	36.66

Table 8.3: Measured weight values (in gm.) of Aquarium-B1 fish group at different time intervals

Aquarium-B1 (Contemporary music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.36	17.45	24.66	33.22
2	10.50	17.66	24.23	33.21
3	10.74	18.03	24.93	34.10
4	10.72	17.99	25.10	34.20
5	10.31	17.52	25.20	34.30
6	10.91	18.20	25.40	33.97
7	10.54	17.65	24.87	34.21
8	10.68	17.83	25.00	34.40
9	10.72	17.69	24.91	34.02
10	10.62	16.90	24.08	33.10
11	10.36	17.41	24.69	33.70
12	10.55	17.83	25.01	33.94
13	10.52	16.99	24.2	32.9
14	10.47	17.63	24.88	34.02
15	10.83	18.04	25.2	34.5

Table 8.4: Measured weight values (in gm.) of Aquarium-C1 fish group at different time intervals

Aquarium-C1 (Control)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.56	15.86	21.42	28.72
2	10.71	15.92	21.56	28.90
3	10.74	16.12	21.89	29.05
4	10.66	15.96	21.72	28.88
5	10.57	15.90	21.82	29.00
6	10.69	16.12	22.03	29.20
7	10.51	15.80	21.49	28.75
8	10.68	16.03	22.10	29.08
9	10.72	16.15	22.21	29.31
10	10.57	15.91	21.98	29.06
11	10.62	16.11	22.12	29.15
12	10.74	16.20	22.21	29.40
13	10.54	15.89	21.57	28.63
14	10.64	16.08	21.99	29.11
15	10.69	16.20	22.04	29.23

Replicate-2

Table 8.5: Measured weight values (in gm.) of Aquarium-A2 fish group at different time intervals

Aquarium-A2 (Indian Classical music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.68	18.52	25.25	35.65
2	10.52	18.61	26.03	35.04
3	10.77	19.02	26.40	36.50
4	10.59	18.71	25.98	36.02
5	10.84	18.99	26.20	36.30
6	10.62	18.92	26.50	36.35
7	10.87	19.42	25.88	35.99
8	10.64	18.63	25.91	35.10
9	10.54	18.75	25.85	35.97
10	10.61	18.95	26.08	36.04
11	10.45	18.69	26.01	35.88
12	10.47	19.05	26.12	36.75
13	10.73	18.75	25.78	36.03
14	10.58	19.10	26.40	36.30
15	10.83	19.79	26.10	36.01

Table 8.6: Measured weight values (in gm.) of Aquarium-B2 fish group at different time intervals

Aquarium-B2 (Contemporary music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.66	17.80	24.98	34.11
2	10.53	17.91	25.06	34.06
3	10.38	17.52	24.74	33.98
4	10.51	18.02	25.42	34.62
5	10.66	17.94	25.11	34.41
6	10.82	18.20	25.60	34.91
7	10.60	18.05	25.08	34.32
8	10.54	18.10	25.30	34.51
9	10.62	17.72	25.04	33.98
10	10.81	18.24	25.75	35.03
11	10.56	17.95	24.99	34.26
12	10.59	17.88	25.01	34.37
13	10.82	18.30	25.41	34.89
14	10.87	18.20	25.34	34.88
15	10.39	17.79	25.06	33.99

Table 8.7: Measured weight values (in gm.) of Aquarium-C2 fish group at different time intervals

Aquarium-C2 (Control)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.77	16.11	22.21	29.31
2	10.65	16.03	21.90	29.18
3	10.59	15.89	21.87	29.23
4	10.63	15.97	22.03	29.10
5	10.88	16.23	22.31	29.44
6	10.62	15.92	22.14	29.02
7	10.67	15.83	21.81	28.89
8	10.71	15.95	21.98	29.07
9	10.83	16.16	22.23	29.22
10	10.79	16.08	22.06	28.89
11	10.55	15.78	21.87	28.35
12	10.68	15.96	21.99	29.09
13	10.63	15.99	22.09	29.20
14	10.81	16.12	22.33	29.31
15	10.85	16.32	22.24	29.28

Replicate-3

Table 8.8: Measured weight values (in gm.) of Aquarium-A3 fish group at different time intervals

Aquarium-A3 (Indian Classical music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.38	17.99	25.77	35.58
2	10.33	18.45	26.66	36.20
3	10.67	18.99	26.94	36.77
4	10.79	19.04	27.02	36.97
5	10.44	18.65	26.84	36.78
6	10.32	18.66	26.98	36.75
7	10.27	18.35	26.55	35.56
8	10.68	19.03	27.10	36.99
9	10.94	19.30	27.50	36.60
10	10.50	18.94	26.78	35.92
11	10.61	18.95	26.09	36.10
12	10.44	18.76	26.65	36.30
13	10.47	19.10	26.95	36.53
14	10.88	19.04	27.10	37.03
15	10.73	19.20	27.50	37.12

Table 8.9: Measured weight values (in gm.) of Aquarium-B3 fish group at different time intervals

Aquarium-B3 (Contemporary music treatment)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.32	17.66	24.56	33.86
2	10.58	17.86	24.97	33.96
3	10.52	17.77	24.99	34.10
4	10.65	17.98	25.17	34.30
5	10.73	18.02	25.32	34.81
6	10.68	17.95	25.91	35.09
7	10.55	17.82	25.06	34.32
8	10.81	18.03	25.30	34.60
9	10.69	17.89	25.01	34.40
10	10.53	17.32	24.62	33.91
11	10.61	17.58	24.87	33.94
12	10.67	18.10	24.95	34.40
13	10.81	18.09	25.01	34.30
14	10.89	18.30	25.50	34.98
15	10.77	18.05	25.11	34.44

Table 8.10: Measured weight values (in gm.) of Aquarium-C3 fish group at different time intervals

Aquarium-C3 (Control)				
Sample no.	Day 1	Day 15	Day 30	day 45
1	10.57	15.87	21.53	28.71
2	10.61	15.89	21.61	28.88
3	10.54	15.65	21.45	28.65
4	10.86	16.03	22.13	29.39
5	10.67	15.78	21.66	28.90
6	10.65	15.98	22.08	29.44
7	10.59	15.72	22.01	29.36
8	10.71	15.97	22.15	29.41
9	10.78	16.01	22.21	29.48
10	10.63	15.87	22.19	29.37
11	10.79	16.21	22.42	29.52
12	10.54	15.94	22.11	29.35
13	10.88	16.13	22.22	29.56
14	10.84	16.09	22.16	29.11
15	10.79	16.12	22.06	29.25

Table 8.11: Measured weight values (in gm.) of music treated and control fish group at different time intervals averaged over three replicates

Fish group	Day 1	Day 15	Day 30	day 45
Classical music treatment	10.39±0.17	18.81±0.3	26.44±0.48	36.21±0.48
Contemporary music treatment	10.62±0.15	17.84±0.3	25.03±0.36	34.21±0.48
Control	10.68±0.1	15.99±0.14	21.98±0.25	29.12±0.26

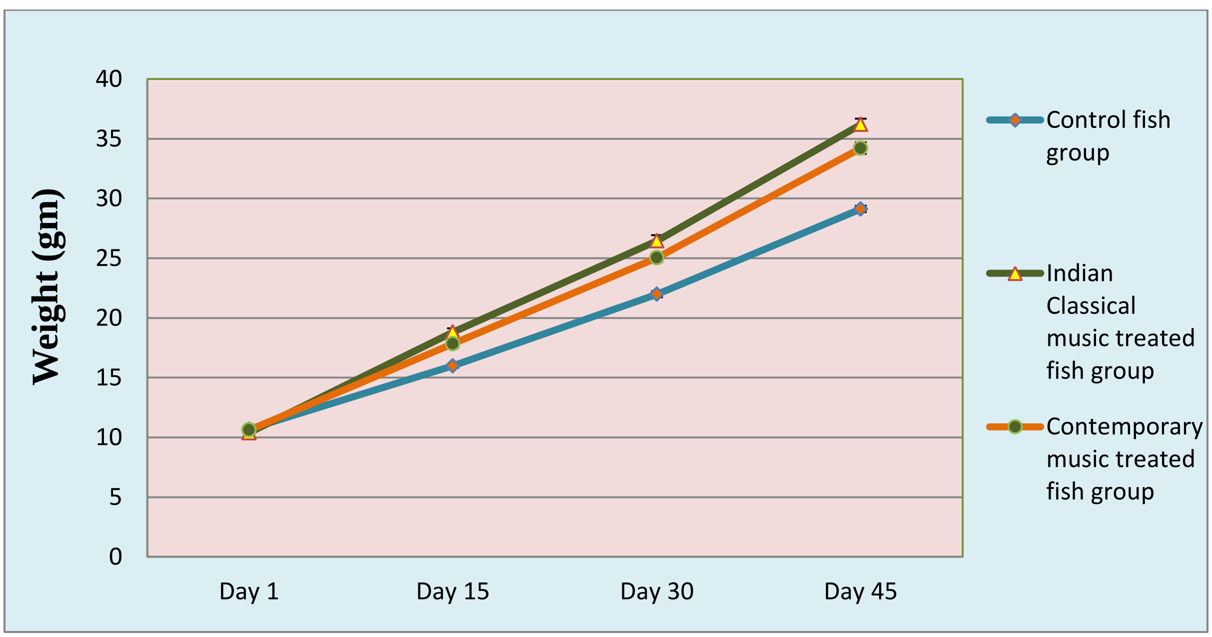


Fig.8.4: Graph comparing measured weight values of Indian Classical music treated, Contemporary music treated and control fish groups averaged over 3 replicates (Vertical bars represent mean ± SD)

Replicate-1

Table 8.12: Weight gain % of fish group in Aquarium-A1

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	36.10	10.75	235.8
2	35.91	10.46	243.3
3	35.78	10.33	246.3
4	35.89	10.58	239.2
5	36.20	10.72	237.6
6	36.07	10.57	241.2
7	37.01	10.83	241.7
8	35.88	10.55	240.0
9	36.33	10.52	245.3
10	36.54	10.67	242.4
11	36.24	10.86	233.7
12	35.96	10.33	248.1
13	36.03	10.82	232.9
14	35.86	10.38	245.4
15	36.66	10.67	243.5

Table 8.13: Weight gain % of fish group in Aquarium-B1

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	33.22	10.36	220.6
2	33.21	10.50	216.2
3	34.10	10.74	217.5
4	34.20	10.72	219.0
5	34.30	10.31	232.6
6	33.97	10.91	211.3
7	34.21	10.54	224.5
8	34.40	10.68	222.0
9	34.02	10.72	217.3
10	33.10	10.62	211.6
11	33.70	10.36	225.2
12	33.94	10.55	221.7
13	32.90	10.52	212.7
14	34.02	10.47	224.9
15	34.50	10.83	218.5

Table 8.14: Weight gain % of fish group in Aquarium-C1

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	28.72	10.56	171.9
2	28.90	10.71	169.8
3	29.05	10.74	170.4
4	28.88	10.66	170.9
5	29.00	10.57	174.3
6	29.20	10.69	173.1
7	28.75	10.51	173.5
8	29.08	10.68	172.2
9	29.31	10.72	173.4
10	29.06	10.57	174.9
11	29.15	10.62	174.4
12	29.40	10.74	173.7
13	28.63	10.54	171.6
14	29.11	10.64	173.5
15	29.23	10.69	173.4

Replicate-2

Table 8.15: Weight gain % of fish group in Aquarium-A2

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	35.65	10.68	233.8
2	35.04	10.52	233.1
3	36.50	10.77	238.9
4	36.02	10.59	240.1
5	36.30	10.84	234.9
6	36.35	10.62	242.3
7	35.99	10.87	231.1
8	35.10	10.64	229.9
9	35.97	10.54	241.3
10	36.04	10.61	239.7
11	35.88	10.45	243.3
12	36.75	10.47	251.0
13	36.03	10.73	235.8
14	36.30	10.58	243.1
15	36.01	10.83	232.5

Table 8.16: Weight gain % of fish group in Aquarium-B2

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	34.11	10.66	220.0
2	34.06	10.53	223.5
3	33.98	10.38	227.4
4	34.62	10.51	229.4
5	34.41	10.66	222.8
6	34.91	10.82	222.6
7	34.32	10.60	223.8
8	34.51	10.54	227.4
9	33.98	10.62	220.0
10	35.03	10.81	224.1
11	34.26	10.56	224.4
12	34.37	10.59	224.6
13	34.89	10.82	222.5
14	34.88	10.87	220.9
15	33.99	10.39	227.1

Table 8.17: Weight gain % of fish group in Aquarium-C2

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	29.31	10.77	172.1
2	29.18	10.65	174.0
3	29.23	10.59	176.0
4	29.10	10.63	173.8
5	29.44	10.88	170.6
6	29.02	10.62	173.3
7	28.89	10.67	170.8
8	29.07	10.71	171.4
9	29.22	10.83	169.8
10	28.89	10.79	167.7
11	28.35	10.55	168.7
12	29.09	10.68	172.4
13	29.20	10.63	174.7
14	29.31	10.81	171.1
15	29.28	10.85	169.9

Replicate-3

Table 8.18:Weight gain % of fish group in Aquarium-A3

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	35.58	10.38	242.7
2	36.20	10.33	250.4
3	36.77	10.67	244.6
4	36.97	10.79	242.6
5	36.78	10.44	252.2
6	36.75	10.32	256.1
7	35.56	10.27	246.2
8	36.99	10.68	246.3
9	36.60	10.94	234.5
10	35.92	10.50	242.0
11	36.10	10.61	240.2
12	36.30	10.44	247.7
13	36.53	10.47	248.9
14	37.03	10.88	240.3
15	37.12	10.73	245.9

Table 8.19: Weight gain % of fish group in Aquarium-B3

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	33.86	10.32	228.1
2	33.96	10.58	221.0
3	34.10	10.52	224.1
4	34.30	10.65	222.1
5	34.81	10.73	224.4
6	35.09	10.68	228.6
7	34.32	10.55	225.3
8	34.60	10.81	220.1
9	34.40	10.69	221.8
10	33.91	10.53	222.0
11	33.94	10.61	219.9
12	34.40	10.67	222.4
13	34.30	10.81	217.3
14	34.98	10.89	221.2
15	34.44	10.77	219.8

Table 8.20: Weight gain % of fish group in Aquarium-C3

Sample no.	Wt (gm.)	W_0 (gm.)	$100 \times (Wt - W_0) \times W_0^{-1}$
1	28.71	10.57	171.6
2	28.88	10.61	172.2
3	28.65	10.54	171.8
4	29.39	10.86	170.6
5	28.90	10.67	170.9
6	29.44	10.65	176.4
7	29.36	10.59	177.2
8	29.41	10.71	174.6
9	29.48	10.78	173.5
10	29.37	10.63	176.3
11	29.52	10.79	173.6
12	29.35	10.54	178.5
13	29.56	10.88	171.7
14	29.11	10.84	168.5
15	29.25	10.79	171.1

Table 8.21: Weight gain % of Indian Classical music treated, Contemporary music treated and control fish group averaged over all the replicates

	Indian Classical music exposed fish group	**Contemporary music exposed fish group**	**Control fish group**
Weight gain %	241.5±5.9	222.0 ±4.4	172.57±2.3

Table 8.21 clearly indicates that music exposure contributed better weight gain % in Nile Tilapia. The Indian Classical music treated fish group, Contemporary music treated fish group, and the untreated control group produced 241.5%, 222.09% and

172.57% body weight gain respectively at the end of the experiment. Figure 8.5 is the graphical representation of Table 8.21.

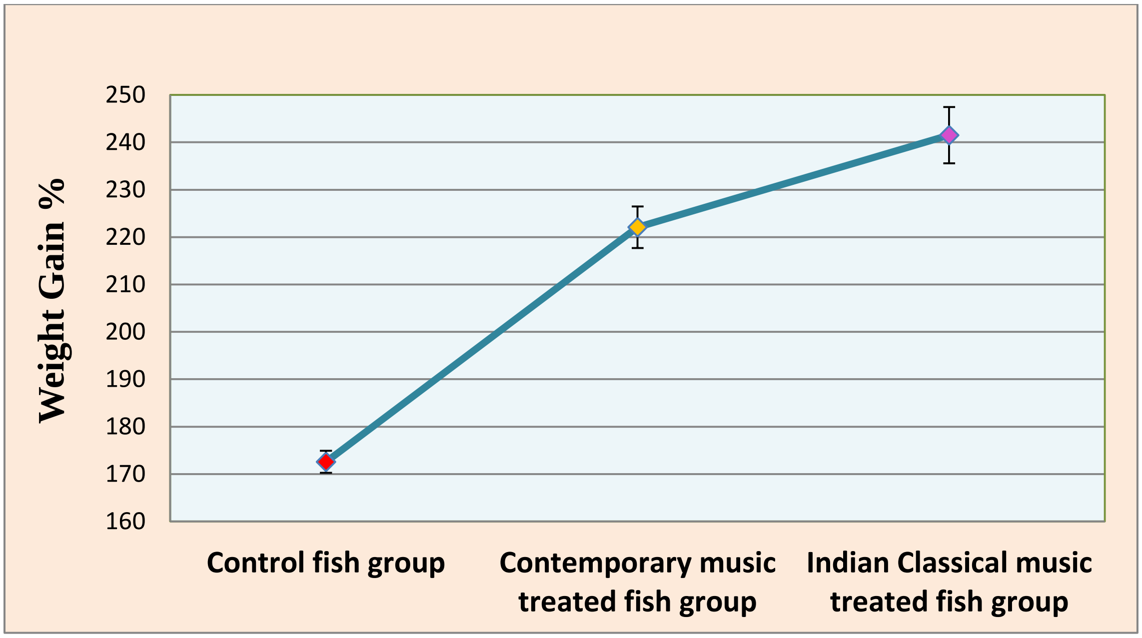


Fig. 8.5: Graph comparing average weight Gain % of Indian Classical music treated, Contemporary music treated and control fish groups at the end of the experiment (Vertical bars represent mean ± SD)

Specific growth rate % was calculated from the direct measured weight values. Table 8.22, Table 8.23, and Table 8.24 manifests the specific growth rate % data of Indian Classical music treated fish group for the first 15 days, from day 16 to day 30 and day 31 to day 45 respectively for replicate 1. Table 8.25, Table 8.26, Table 8.27 represents the same for Contemporary music treated fish group and Table 8.28, Table 8.29, and Table 8.30 shows the specific growth rate % of the untreated control fish group of the above mentioned time duration respectively. For replicate- 2, Table 8.31, Table 8.32, and Table 8.33 shows the specific growth rate % data of Indian Classical music treated fish group for the first 15 days, from day 16 to day 30 and day 31 to day 45 respectively. Table 8.34, Table 8.35, and Table 8.36 manifests the same for Contemporary music treated fish group and Table

8.37, Table 8.38, and Table 8.39 exhibits the specific growth rate % data of untreated control fish group for the first 15 days, from day 16 to day 30 and day 31 to day 45 respectively. Table 8.40, Table 8.41, and Table 8.42 manifests the specific growth rate % data of the above mentioned time duration for Indian Classical music treated fish group for replicate-3, Table 8.43, Table 8.44, Table 8.45; and Table 8.46, Table 8.47, Table 8.48 represents the same for Contemporary music treated and untreated control fish group respectively. Table 8.49 shows the specific growth rate (SGR % day^{-1}) of Indian Classical music treated, Contemporary music treated and control fish group after the above specified time intervals averaged over three replicates.

Replicate-1

Table 8.22: Specific growth rate (SGR % day^{-1}) of Aquarium-A1 fish group for initial 15 days

Sample no.	Wt	W_0	$100 \times (\text{Ln Wt - Ln } W_0) \times T^{-1}$
1	19.02	10.75	1.7
2	18.94	10.46	1.8
3	18.56	10.33	1.8
4	18.97	10.58	1.8
5	19.10	10.72	1.7
6	18.88	10.57	1.7
7	18.99	10.83	1.7
8	18.85	10.55	1.8
9	19.05	10.52	1.8
10	19.24	10.67	1.8
11	19.13	10.86	1.7
12	18.56	10.33	1.8
13	19.24	10.82	1.7
14	18.68	10.38	1.8
15	19.09	10.67	1.8

Table 8.23: **Specific growth rate (SGR % day^{-1}) of Aquarium-A1 fish group from day 16 to day 30**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	26.05	19.02	0.9
2	26.20	18.94	0.9
3	25.87	18.56	0.9
4	26.09	18.97	0.9
5	26.40	19.10	0.9
6	26.13	18.88	0.9
7	26.52	18.99	0.9
8	25.96	18.85	0.9
9	26.31	19.05	0.9
10	26.76	19.24	0.9
11	26.68	19.13	0.9
12	25.89	18.56	0.9
13	26.34	19.24	0.9
14	26.07	18.68	0.9
15	26.46	19.09	0.9

Table 8.24: **Specific growth rate (SGR % day^{-1}) of Aquarium-A1 fish group from day 31 today 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	36.10	26.05	0.9
2	35.91	26.20	0.9
3	35.78	25.87	0.9
4	35.89	26.09	0.9
5	36.20	26.40	0.9
6	36.07	26.13	0.9
7	37.01	26.52	0.9
8	35.88	25.96	0.9
9	36.33	26.31	0.9
10	36.54	26.76	0.9
11	36.24	26.68	0.8
12	35.96	25.89	0.9
13	36.03	26.34	0.9
14	35.86	26.07	0.9
15	36.66	26.46	0.9

Table 8.25: **Specific growth rate (SGR % day^{-1}) of Aquarium-B1 fish group for initial 15 days**

Sample no.	Wt	W_0	$100 \times (\ln Wt - \ln W_0) \times T^{-1}$
1	17.45	10.36	1.6
2	17.66	10.50	1.6
3	18.03	10.74	1.6
4	17.99	10.72	1.6
5	17.52	10.31	1.6
6	18.2	10.91	1.5
7	17.65	10.54	1.5
8	17.83	10.68	1.5
9	17.69	10.72	1.5
10	16.9	10.62	1.4
11	17.41	10.36	1.6
12	17.83	10.55	1.6
13	16.99	10.52	1.4
14	17.63	10.47	1.6
15	18.04	10.83	1.5

Table 8.26: **Specific growth rate (SGR % day^{-1}) of Aquarium-B1 fish group from day 16 to day 30**

Sample no.	Wt	W_0	$100 \times (\ln Wt - \ln W_0) \times T^{-1}$
1	24.66	17.45	1.0
2	24.23	17.66	0.9
3	24.93	18.03	0.9
4	25.10	17.99	0.9
5	25.20	17.52	1.0
6	25.40	18.20	0.9
7	24.87	17.65	0.9
8	25.00	17.83	0.9
9	24.91	17.69	0.9
10	24.08	16.90	1.0
11	24.69	17.41	1.0
12	25.01	17.83	0.9
13	24.20	16.99	1.0
14	24.88	17.63	0.9
15	25.20	18.04	0.9

Table 8.27: **Specific growth rate (SGR % day^{-1}) of Aquarium-B1 fish group from day 31 to day 45**

Sample no.	Wt	W_0	$100 \times (\text{Ln Wt} - \text{Ln } W_0) \times T^{-1}$
1	33.22	24.66	0.8
2	33.21	24.23	0.9
3	34.10	24.93	0.9
4	34.20	25.10	0.8
5	34.30	25.20	0.8
6	33.97	25.40	0.8
7	34.21	24.87	0.9
8	34.40	25.00	0.9
9	34.02	24.91	0.9
10	33.10	24.08	0.9
11	33.70	24.69	0.9
12	33.94	25.01	0.8
13	32.90	24.20	0.8
14	34.02	24.88	0.9
15	34.50	25.20	0.9

Table 8.28: **Specific growth rate (SGR % day^{-1}) of Aquarium-C1 fish group for initial 15 days**

Sample no.	Wt	W_0	$100 \times (\text{Ln Wt} - \text{Ln } W_0) \times T^{-1}$
1	15.86	10.56	1.2
2	15.92	10.71	1.2
3	16.12	10.74	1.2
4	15.96	10.66	1.2
5	15.90	10.57	1.2
6	16.12	10.69	1.2
7	15.80	10.51	1.2
8	16.03	10.68	1.2
9	16.15	10.72	1.2
10	15.91	10.57	1.2
11	16.11	10.62	1.2
12	16.20	10.74	1.2
13	15.89	10.54	1.2
14	16.08	10.64	1.2
15	16.20	10.69	1.2

Table 8.29: **Specific growth rate (SGR % day^{-1}) of Aquarium-C1 fish group from day 16 to day 30**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	21.42	15.86	0.8
2	21.56	15.92	0.8
3	21.89	16.12	0.8
4	21.72	15.96	0.8
5	21.82	15.90	0.9
6	22.03	16.12	0.9
7	21.49	15.80	0.8
8	22.10	16.03	0.9
9	22.21	16.15	0.9
10	21.98	15.91	0.9
11	22.12	16.11	0.9
12	22.21	16.20	0.9
13	21.57	15.89	0.8
14	21.99	16.08	0.9
15	22.04	16.20	0.8

Table 8.30: **Specific growth rate (SGR % day^{-1}) of Aquarium-C1 fish group from day 31 to day 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	28.72	21.42	0.8
2	28.90	21.56	0.8
3	29.05	21.89	0.8
4	28.88	21.72	0.8
5	29.00	21.82	0.8
6	29.20	22.03	0.8
7	28.75	21.49	0.8
8	29.08	22.10	0.7
9	29.31	22.21	0.8
10	29.06	21.98	0.8
11	29.15	22.12	0.7
12	29.40	22.21	0.8
13	28.63	21.57	0.8
14	29.11	21.99	0.8
15	29.23	22.04	0.8

Replicate-2

Table 8.31: Specific growth rate (SGR % day^{-1}) of Aquarium-A2 fish group for initial 15 days

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	18.52	10.68	1.7
2	18.61	10.52	1.7
3	19.02	10.77	1.7
4	18.71	10.59	1.7
5	18.99	10.84	1.7
6	18.92	10.62	1.7
7	19.42	10.87	1.8
8	18.63	10.64	1.7
9	18.75	10.54	1.7
10	18.95	10.61	1.7
11	18.69	10.45	1.8
12	19.05	10.47	1.8
13	18.75	10.73	1.7
14	19.10	10.58	1.8
15	19.79	10.83	1.8

Table 8.32: Specific growth rate (SGR % day^{-1}) of Aquarium-A2 fish group from day 16 to day 30

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	25.25	18.52	0.8
2	26.03	18.61	0.9
3	26.40	19.02	0.9
4	25.98	18.71	0.9
5	26.20	18.99	0.9
6	26.50	18.92	0.9
7	25.88	19.42	0.8
8	25.91	18.63	0.9
9	25.85	18.75	0.9
10	26.08	18.95	0.9
11	26.01	18.69	0.9
12	26.12	19.05	0.9
13	25.78	18.75	0.9
14	26.40	19.10	0.9
15	26.10	19.79	0.8

Table 8.33: Specific growth rate (SGR % day^{-1}) of Aquarium-A2 fish group from day 31 today 45

Sample no.	Wt	W_0	$100 \times (\text{Ln Wt} - \text{Ln } W_0) \times T^{-1}$
1	35.65	25.25	0.9
2	35.04	26.03	0.8
3	36.50	26.40	0.9
4	36.02	25.98	0.9
5	36.30	26.20	0.9
6	36.35	26.50	0.9
7	35.99	25.88	0.9
8	35.10	25.91	0.8
9	35.97	25.85	0.9
10	36.04	26.08	0.9
11	35.88	26.01	0.9
12	36.75	26.12	0.9
13	36.03	25.78	0.9
14	36.30	26.40	0.9
15	36.01	26.10	0.9

Table 8.34: Specific growth rate (SGR % day^{-1}) of Aquarium-B2 fish group for initial 15 days

Sample no.	Wt	W_0	$100 \times (\text{Ln Wt} - \text{Ln } W_0) \times T^{-1}$
1	17.80	10.66	1.5
2	17.91	10.53	1.6
3	17.52	10.38	1.6
4	18.02	10.51	1.6
5	17.94	10.66	1.6
6	18.20	10.82	1.6
7	18.05	10.60	1.6
8	18.10	10.54	1.6
9	17.72	10.62	1.5
10	18.24	10.81	1.6
11	17.95	10.56	1.6
12	17.88	10.59	1.6
13	18.30	10.82	1.6
14	18.20	10.87	1.5
15	17.79	10.39	1.6

Table 8.35: **Specific growth rate (SGR % day^{-1}) of Aquarium-B2 fish group from day 16 to day 30**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	24.98	17.80	0.9
2	25.06	17.91	0.9
3	24.74	17.52	0.9
4	25.42	18.02	0.9
5	25.11	17.94	0.9
6	25.60	18.20	0.9
7	25.08	18.05	0.9
8	25.30	18.10	0.9
9	25.04	17.72	1.0
10	25.75	18.24	0.9
11	24.99	17.95	0.9
12	25.01	17.88	0.9
13	25.41	18.30	0.9
14	25.34	18.20	0.9
15	25.06	17.79	0.9

Table 8.36: **Specific growth rate (SGR % day^{-1}) of Aquarium-B2 fish group from day 31 to day 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	34.11	24.98	0.9
2	34.06	25.06	0.8
3	33.98	24.74	0.9
4	34.62	25.42	0.8
5	34.41	25.11	0.9
6	34.91	25.60	0.8
7	34.32	25.08	0.9
8	34.51	25.30	0.8
9	33.98	25.04	0.8
10	35.03	25.75	0.8
11	34.26	24.99	0.9
12	34.37	25.01	0.9
13	34.89	25.41	0.9
14	34.88	25.34	0.9
15	33.99	25.06	0.8

Table 8.37: **Specific growth rate (SGR % day^{-1}) of Aquarium-C2 fish group for initial 15 days**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	16.11	10.77	1.2
2	16.03	10.65	1.2
3	15.89	10.59	1.2
4	15.97	10.63	1.2
5	16.23	10.88	1.2
6	15.92	10.62	1.2
7	15.83	10.67	1.2
8	15.95	10.71	1.2
9	16.16	10.83	1.2
10	16.08	10.79	1.2
11	15.78	10.55	1.2
12	15.96	10.68	1.2
13	15.99	10.63	1.2
14	16.12	10.81	1.2
15	16.32	10.85	1.2

Table 8.38: **Specific growth rate (SGR % day^{-1}) of Aquarium-C2 fish group from day 16 to day 30**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	22.21	16.11	0.9
2	21.90	16.03	0.9
3	21.87	15.89	0.9
4	22.03	15.97	0.9
5	22.31	16.23	0.9
6	22.14	15.92	0.9
7	21.81	15.83	0.9
8	21.98	15.95	0.9
9	22.23	16.16	0.9
10	22.06	16.08	0.9
11	21.87	15.78	0.9
12	21.99	15.96	0.9
13	22.09	15.99	0.9
14	22.33	16.12	0.9
15	22.24	16.32	0.8

Table 8.39: **Specific growth rate (SGR % day^{-1}) of Aquarium-C2 fish group from day 31 to day 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	29.31	22.21	0.8
2	29.18	21.90	0.8
3	29.23	21.87	0.8
4	29.10	22.03	0.8
5	29.44	22.31	0.8
6	29.02	22.14	0.7
7	28.89	21.81	0.8
8	29.07	21.98	0.8
9	29.22	22.23	0.7
10	28.89	22.06	0.7
11	28.35	21.87	0.7
12	29.09	21.99	0.8
13	29.20	22.09	0.8
14	29.31	22.33	0.7
15	29.28	22.24	0.7

Replicate-3

Table 8.40: Specific growth rate (SGR % day^{-1}) of Aquarium-A3 fish group for initial 15 days

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	17.99	10.38	1.7
2	18.45	10.33	1.7
3	18.99	10.67	1.7
4	19.04	10.79	1.7
5	18.65	10.44	1.7
6	18.66	10.32	1.8
7	18.35	10.27	1.8
8	19.03	10.68	1.7
9	19.30	10.94	1.7
10	18.94	10.50	1.8
11	18.95	10.61	1.7
12	18.76	10.44	1.8
13	19.10	10.47	1.8
14	19.04	10.88	1.7
15	19.20	10.73	1.8

Table 8.41: **Specific growth rate (SGR % day^{-1}) of Aquarium-A3 fish group from day 16 to day 30**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	25.77	17.99	1
2	26.66	18.45	1
3	26.94	18.99	1
4	27.02	19.04	1
5	26.84	18.65	1
6	26.98	18.66	1
7	26.55	18.35	1
8	27.10	19.03	1
9	27.50	19.30	1
10	26.78	18.94	1
11	26.09	18.95	0.9
12	26.65	18.76	1
13	26.95	19.10	0.9
14	27.10	19.04	1
15	27.50	19.20	1

Table 8.42: **Specific growth rate (SGR % day^{-1}) of Aquarium-A3 fish group from day 31 today 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	35.58	25.77	0.9
2	36.20	26.66	0.8
3	36.77	26.94	0.9
4	36.97	27.02	0.9
5	36.78	26.84	0.9
6	36.75	26.98	0.8
7	35.56	26.55	0.8
8	36.99	27.10	0.9
9	36.60	27.50	0.8
10	35.92	26.78	0.8
11	36.10	26.09	0.9
12	36.30	26.65	0.8
13	36.53	26.95	0.8
14	37.03	27.10	0.9
15	37.12	27.50	0.8

Table 8.43: **Specific growth rate (SGR % day^{-1}) of Aquarium-B3 fish group for initial 15 days**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	17.66	10.32	1.6
2	17.86	10.58	1.6
3	17.77	10.52	1.6
4	17.98	10.65	1.6
5	18.02	10.73	1.6
6	17.95	10.68	1.6
7	17.82	10.55	1.6
8	18.03	10.81	1.5
9	17.89	10.69	1.5
10	17.32	10.53	1.5
11	17.58	10.61	1.5
12	18.10	10.67	1.6
13	18.09	10.81	1.5
14	18.30	10.89	1.6
15	18.05	10.77	1.6

Table 8.44: **Specific growth rate (SGR % day^{-1}) of Aquarium-B3 fish group from day 16 to day 30**

Sample no	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	24.56	17.66	0.9
2	24.97	17.86	0.9
3	24.99	17.77	0.9
4	25.17	17.98	0.9
5	25.32	18.02	0.9
6	25.91	17.95	1.0
7	25.06	17.82	0.9
8	25.30	18.03	0.9
9	25.01	17.89	0.9
10	24.62	17.32	1.09
11	24.87	17.58	1.0
12	24.95	18.10	0.9
13	25.01	18.09	0.9
14	25.50	18.30	0.9
15	25.11	18.05	0.9

Table 8.45: **Specific growth rate (SGR % day^{-1}) of Aquarium-B3 fish group from day 31 to day 45**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	33.86	24.56	0.9
2	33.96	24.97	0.8
3	34.10	24.99	0.8
4	34.30	25.17	0.8
5	34.81	25.32	0.9
6	35.09	25.91	0.8
7	34.32	25.06	0.9
8	34.60	25.30	0.9
9	34.40	25.01	0.9
10	33.91	24.62	0.9
11	33.94	24.87	0.9
12	34.40	24.95	0.9
13	34.30	25.01	0.9
14	34.98	25.50	0.9
15	34.44	25.11	0.9

Table 8.46: **Specific growth rate (SGR % day^{-1}) of Aquarium-C3 fish group for initial 15 days**

Sample no.	Wt	W_0	100 × (Ln Wt - Ln W_0) x T^{-1}
1	15.87	10.57	1.2
2	15.89	10.61	1.2
3	15.65	10.54	1.2
4	16.03	10.86	1.2
5	15.78	10.67	1.2
6	15.98	10.65	1.2
7	15.72	10.59	1.2
8	15.97	10.71	1.2
9	16.01	10.78	1.2
10	15.87	10.63	1.2
11	16.21	10.79	1.2
12	15.94	10.54	1.2
13	16.13	10.88	1.2
14	16.09	10.84	1.2
15	16.12	10.79	1.2

Table 8.47: **Specific growth rate (SGR % day^{-1}) of Aquarium-C3 fish group from day 16 to day 30**

Sample no.	Wt	W_0	$100 \times (\ln Wt - \ln W_0) \times T^{-1}$
1	21.53	15.87	0.8
2	21.61	15.89	0.8
3	21.45	15.65	0.9
4	22.13	16.03	0.9
5	21.66	15.78	0.9
6	22.08	15.98	0.9
7	22.01	15.72	0.9
8	22.15	15.97	0.9
9	22.21	16.01	0.9
10	22.19	15.87	0.9
11	22.42	16.21	0.9
12	22.11	15.94	0.9
13	22.22	16.13	0.9
14	22.16	16.09	0.9
15	22.06	16.12	0.9

Table 8.48: **Specific growth rate (SGR % day^{-1}) of Aquarium-C3 fish group from day 31 to day 45**

Sample no.	Wt	W_0	$100 \times (\ln Wt - \ln W_0) \times T^{-1}$
1	28.71	21.53	0.8
2	28.88	21.61	0.8
3	28.65	21.45	0.8
4	29.39	22.13	0.8
5	28.90	21.66	0.8
6	29.44	22.08	0.8
7	29.36	22.01	0.8
8	29.41	22.15	0.8
9	29.48	22.21	0.8
10	29.37	22.19	0.8
11	29.52	22.42	0.7
12	29.35	22.11	0.8
13	29.56	22.22	0.8
14	29.11	22.16	0.7
15	29.25	22.06	0.8

Table 8.49: **Specific growth rate (SGR % day^{-1}) of Indian Classical music treated, Contemporary music treated and control fish group after specific time intervals averaged over three replicates**

Fish group	Day 1-15	Day 16-30	Day 31-45
Indian Classical music treatment	1.74±0.05	0.92±0.05	0.87±0.04
Contemporary music treatment	1.56±0.05	0.92±0.04	0.86±0.04
Control	1.2±0.06	0.87±0.04	0.77±0.04

The Table 8.49 speaks itself. Throughout the whole experimental time period music exposed fish groups showed better results than untreated control fish group. From day 1 to day 15 the SGR % was highest in case of Indian Classical music exposed fish group (1.74%) followed by Contemporary music exposed fish group (1.56%), and untreated control fish group (1.2%). In between day 16 to day 30 both the Indian Classical music as well as Contemporary music exposed fish groups exhibited 0.92% SGR and the control fishes showed 0.87% SGR. From day 31 to the end of the experiment that is up to day 45the Indian Classical music exposed fish group (0.87%) and Contemporary music exposed fish group (0.86%) exhibited almost same SGR but both the music take over control fish group (0.77%). But overall form the beginning to the end of the experiment the Indian Classical musicexposed fish group, Contemporary music exposed fish group and untreated control fish group exhibited 1.18%, 1.12%, and 0.96% average SGR respectively. Figure 8.6 is the graphical representation of Table 8.49.

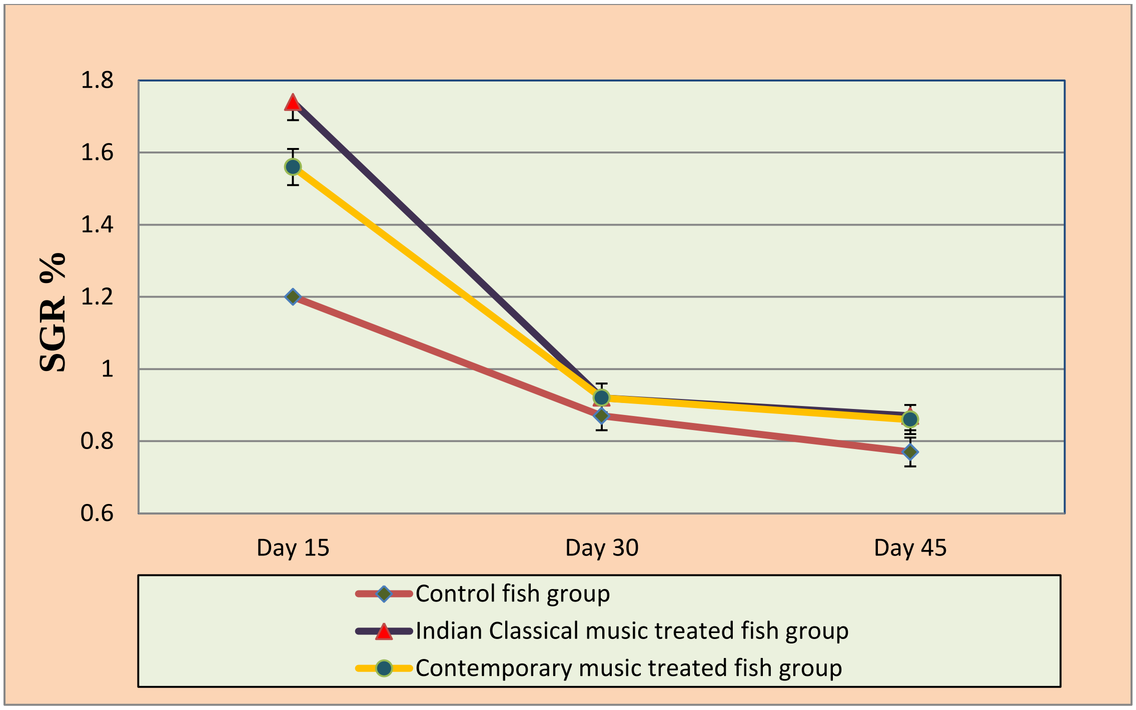


Fig.8.6: Graph comparing average SGR% of Indian Classical music treated, Contemporary music treated, and control fish groups after specific time intervals (Vertical bars represent mean ± SD)

Table 8.50, Table 8.51 and Table 8.52 shows the replicate-1 data input of initial and final fish length of Classical music treated, Contemporary music treated and untreated control group respectively.Table 8.53, Table 8.54 and Table 8.55 represents the same for replicate-2 and Table 8.56, Table 8.57 and Table 8.58 for replicate-3 respectively.Table 8.59 shows the average initial length, final length and length gain % values of the three fish groups together. Table 8.59 clearly depicts that Indian Classical music exhibited highest body length gain % (72.4%) in Nile Tilapia followed by contemporary music (61.09%) and untreated control group (48.4%). Figure 8.7 has drawn from the Table 8.59 to make the result more perceivable.

Replicate-1

Table 8.50: Initial and final length measurement values (in cm.) of Aquarium A1 fish group

Aquarium-A1(Indian Classical music treatment)		
Sample no.	Day 1	Day 45
1	8.7	14.2
2	8.5	14.6
3	8.6	14.5
4	8.3	14.1
5	8.8	14.0
6	8.2	14.0
7	8.6	14.7
8	8.2	13.9
9	8.0	14.1
10	8.1	14.4
11	8.6	14.2
12	7.9	13.7
13	8.6	14.1
14	8.0	14.3
15	8.3	14.6

Table 8.51: Initial and final length measurement values (in cm.) of Aquarium B1 fish group

Aquarium-B1 (Contemporary music treatment)		
Sample no.	Day 1	Day 45
1	8.0	13.5
2	8.3	13.8
3	8.2	13.0
4	8.8	13.5
5	8.6	13.6
6	8.1	13.8
7	8.0	13.7
8	8.1	14.0
9	8.0	13.4
10	8.1	13.1
11	8.6	13.0
12	8.8	13.3
13	8.2	13.0
14	8.6	13.4
15	8.3	13.5

Table 8.52: Initial and final length measurement values (in cm.) of Aquarium C1 fish group

Aquarium-C1 (Control)		
Sample no.	Day 1	Day 45
1	8.2	11.8
2	7.9	12.2
3	8.5	12.8
4	8.1	11.9
5	8.3	12.9
6	8.4	12.3
7	8.4	12.4
8	8.2	12.7
9	8.4	12.9
10	8.1	12.8
11	8.6	12.2
12	8.4	12.1
13	8.3	12.3
14	8.1	12.2
15	8.2	12.5

Replicate-2

Table 8.53: Initial and final length measurement values (in cm.) of Aquarium A2 fish group

Aquarium-A2 (Indian Classical music treatment)		
Sample no.	Day 1	Day 45
1	8.6	14.2
2	8.8	14.0
3	8.7	14.2
4	8.2	14.5
5	8.3	14.6
6	8.5	14.0
7	8.0	13.9
8	8.1	13.8
9	8.0	14.0
10	8.2	14.2
11	8.0	14.1
12	7.9	14.6
13	8.3	14.4
14	8.2	14.2
15	8.5	14.6

Table 8.54: Initial and final length measurement values (in cm.) of Aquarium B2 fish group

Aquarium-B2 (Contemporary music treatment)		
Sample no.	Day 1	Day 45
1	8.7	13.6
2	8.3	13.0
3	8.2	13.2
4	8.7	13.9
5	8.5	13.2
6	8.9	14.0
7	9.0	13.1
8	8.8	13.0
9	8.2	13.2
10	8.6	14.1
11	8.3	14.3
12	8.2	13.3
13	9.1	13.8
14	8.3	13.1
15	8.5	14.0

Table 8.55: Initial and final length measurement values (in cm.) of Aquarium C2 fish group

Aquarium-C2 (Control)		
Sample no.	Day 1	Day 45
1	8.3	12.4
2	8.2	12.0
3	7.8	12.1
4	8.4	11.9
5	8.6	12.7
6	8.4	12.0
7	8.2	12.1
8	8.2	11.9
9	8.4	12.1
10	8.5	11.8
11	7.9	12.0
12	8.3	12.4
13	8.3	12.3
14	8.5	12.5
15	8.3	12.6

Replicate-3

Table 8.56: Initial and final length measurement values (in cm.) of Aquarium A3 fish group

Aquarium-A3 (Indian Classical musictreatment)		
Sample no.	Day 1	Day 45
1	8.3	14.5
2	8.0	14.2
3	8.2	14.7
4	8.1	14.9
5	8.5	15.0
6	8.3	14.3
7	8.0	14.8
8	8.3	14.5
9	8.6	14.1
10	8.1	14.0
11	8.2	14.2
12	8.2	14.4
13	8.0	14.5
14	8.4	13.9
15	8.7	15.0

Table 8.57: Initial and final length measurement values (in cm.) of Aquarium B3 fish group

Aquarium-B3(Contemporary music treatment)		
Sample no.	Day 1	Day 45
1	8.1	13.9
2	8.0	13.8
3	7.8	13.2
4	8.6	14.0
5	8.6	13.8
6	8.7	13.2
7	8.2	14.1
8	8.5	13.5
9	8.4	13.4
10	8.2	13.1
11	8.8	14.1
12	8.3	14.4
13	8.9	13.8
14	9.0	14.0
15	8.6	14.2

Table 8.58: Initial and final length measurement values (in cm.) of Aquarium C3 fish group

Aquarium-C3 (Control)		
Sample no.	Day 1	Day 45
1	7.9	12.3
2	8.1	11.9
3	7.9	12.1
4	8.4	12.8
5	8.2	11.9
6	8.4	12.5
7	8.3	12.7
8	8.6	12.3
9	8.5	12.5
10	8.2	12.4
11	8.5	12.2
12	7.8	12.0
13	8.5	12.1
14	8.4	11.8
15	8.5	12.4

Table 8.59: Initial and final length measurement values (in cm.) along with length gain % of Indian Classical music treated, Contemporary music treated and control fish group averaged over all the replicates

	Indian Classical music exposed fish group	**Contemporary music exposed fish group**	**Control fish group**
Initial length (cm.)	8.3±0.25	8.43±0.32	8.28±0.21
Final length (cm.)	14.3±0.31	13.57±0.4	12.28±0.31
Length gain %	72.45±6.23	61.09±7.21	48.41±4.67

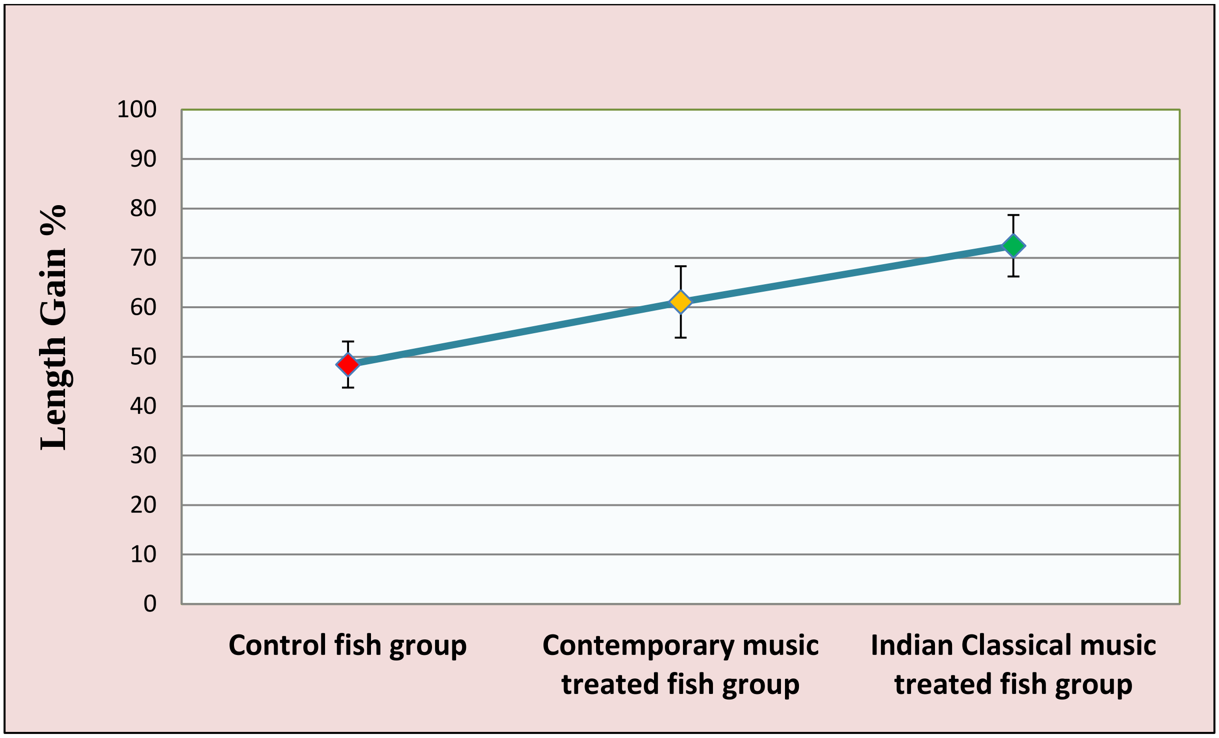


Fig. 8.7: Graph comparing average length Gain % of Indian Classical music treated, Contemporary music treated and control fish groups at the end of the experiment (Vertical bars represent mean ± SD)

8.4.3 ANALYSIS OF BLOOD PARAMETER

Table 8.60 depicts the measured plasma cortisol levels of replicate-1 Indian Classical music treated, Contemporary music treated, and control fish group respectively. Table 8.61 and Table 8.62 present the plasma cortisol values of the three fish groups for replicate-2 and replicate-3 sequentially.Table 8.63 shows plasma cortisol values of the Indian Classical music exposed, contemporary music exposed, and untreated control fish groups averaged over all the replicates. Figure 8.8 is the graphical representation of Table 8.63 which shows the plasma cortisol concentrations of three fish groups together.

Table 8.60: Plasma cortisol concentration (ng/ml) of both the music treated and untreated replicate-1fish groups

	Aquarium A1 (Indian Classical music treatment)	Aquarium B1 (Contemporary music treatment)	Aquarium C1 (Control)
1	27.34	29.26	31.82
2	26.95	26.75	29.77
3	28.08	29.28	30.69
4	29.62	28.57	29.22
5	28.16	28.89	32.13

Table 8.61: Plasma cortisol concentration (ng/ml) of both the music treated and untreated replicate-2 fish group

	Aquarium A2 (Indian Classical music treatment)	Aquarium B2 (Contemporary music treatment)	Aquarium C2 (Control)
1	28.14	29.82	31.62
2	28.95	29.36	30.82
3	26.32	28.21	30.03
4	27.65	27.48	29.75
5	28.34	28.29	30.16

Table 8.62: Plasma cortisol concentration (ng/ml) of both the music treated and untreated replicate-3 fish group

	Aquarium A3 (Indian Classical music treatment)	Aquarium B3 (Contemporary music treatment)	Aquarium C3 (Control)
1	28.42	29.42	31.54
2	27.93	27.17	29.86
3	28.06	29.53	29.67
4	26.85	28.92	32.14
5	27.35	30.11	30.34

Table 8.63: Plasma cortisol concentration (ng/ml) of both the music treated and untreated fish groups averaged over all replicates

	Indian Classical music treated fish group	Contemporary music treated fish group	Control fish group
Plasma Cortisol level (ng/ml)	27.87±0.98	28.73±0.84	30.63±0.98

Table 8.63 clearly indicates that music exposed fish groups exhibited lower plasma cortisol levels than the untreated control fish group. The highest value of plasma cortisol level was observed in untreated control fish group (30.63 ng/ml) followed by Contemporary music treated fish group (28.73 ng/ml) and Indian Classical music treated fish group (27.87 ng/ml) respectively.

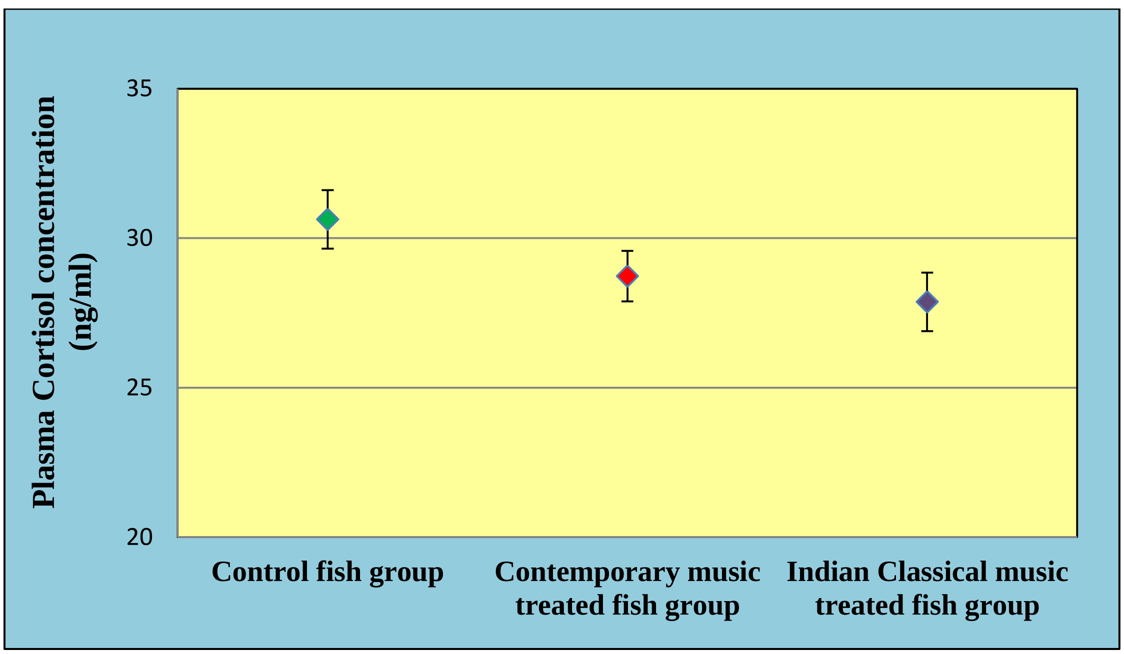


Fig. 8.8: Graph comparing average plasma cortisol concentrationof Indian Classical music treated, Contemporary music treated and control fish groups at the end of the experiment (Vertical bars represent mean ± SD)

8.4.4 EFFECT OF DFA SCALING EXPONENTS ON NILE TILAPIA

From the above findings it is very evident that the Indian classical and Contemporary music treated fishes grew much faster than the untreated control fish group. The music treated fish groups showed significantly higher wait gain %, specific growth rate %, and length gain % when compared to untreated control fish group. Interestingly, Nile Tilapia subjected to Indian Classical music with mean DFA exponent value of 1.683 showed better results than the Contemporary music with DFA value of 0.778. Here also, Indian Classical music with highest order of self- similarity takes over Contemporary music .The above results clearly revealed that the differences in fish weight gain, specific growth rate and final length did not happen by chance but music stimulation was the reason responsible for such differences in growth parameters. Like growth parameters, blood parameter was also significantly affected by music treatments. Figure 8.9, Figure 8.10, Figure 8.11, and Figure 8.12 depicts the relationship between differences in final weight gain %, SGR %, length gain %, and plasma cortisol concentration % of two different music stimuli exposed Nile Tilapia relative to control and corresponding DFA scaling exponent values of music signals. At the end of the experiment, the Indian Classical music exposed fish group showed 39.9% higher weight gain, 22.4% greater SGR % and 16.5 % increased final body length than the untreated control fishes. On the other hand Contemporary music exposed fishes exhibited 28.6 % higher weight gain %, 16.6 % greater SGR % and 10.6 % increased final body length than the untreated control fishes. Moreover significant decreases in serum cortisol levels were observed at the two music treatments.The Indian Classical music exposed fish group exhibited 8.9 %and Contemporary music exposed fishes exhibited 6.1 % reduced plasma cortisol concentration than the untreated control fish group. Plasma cortisol is considered a good acute stress marker. Here, in captivity different physical factors like confinement, handling, repeated capture and release directly acted on in Nile tilapia manifested as an increased plasma cortisol level. Concerning the plasma cortisol levels, the obtained results indicated that music can cause decreased stress responses in Nile tilapia fish.

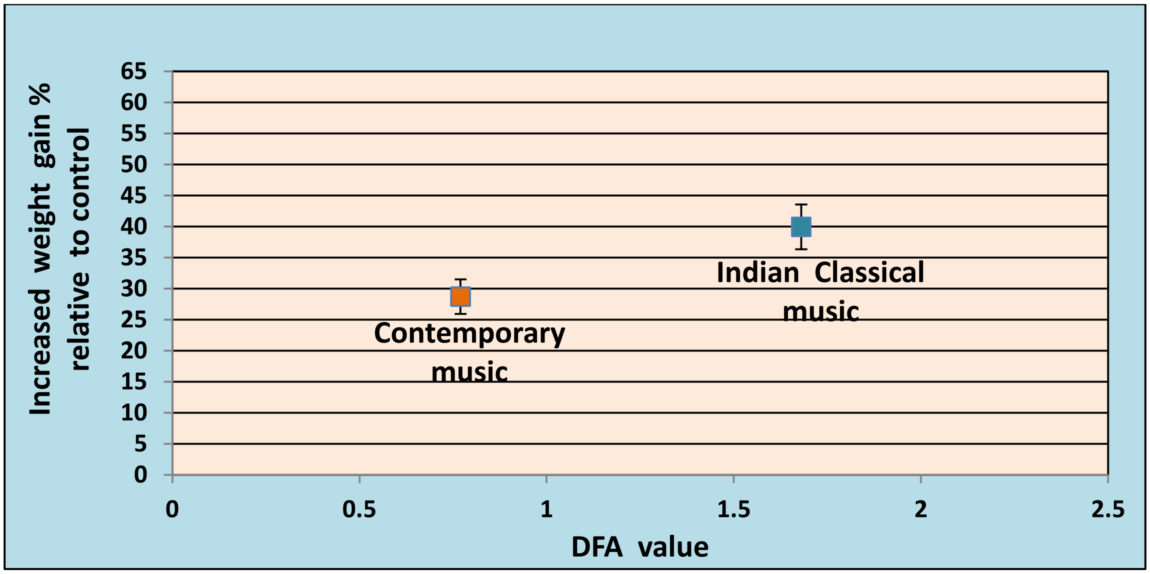


Fig.8.9: Graph comparing increased weight gain % of two different kinds of music stimulated fish groups over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

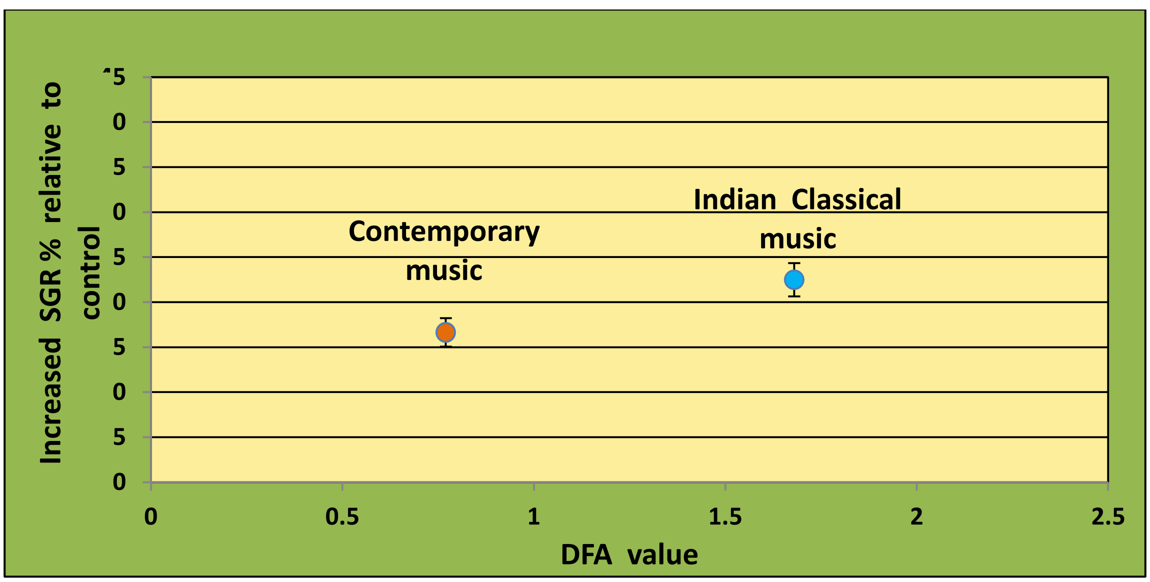


Fig.8.10: Graph comparing increased SGR % of two different kinds of music stimulated fish groups over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

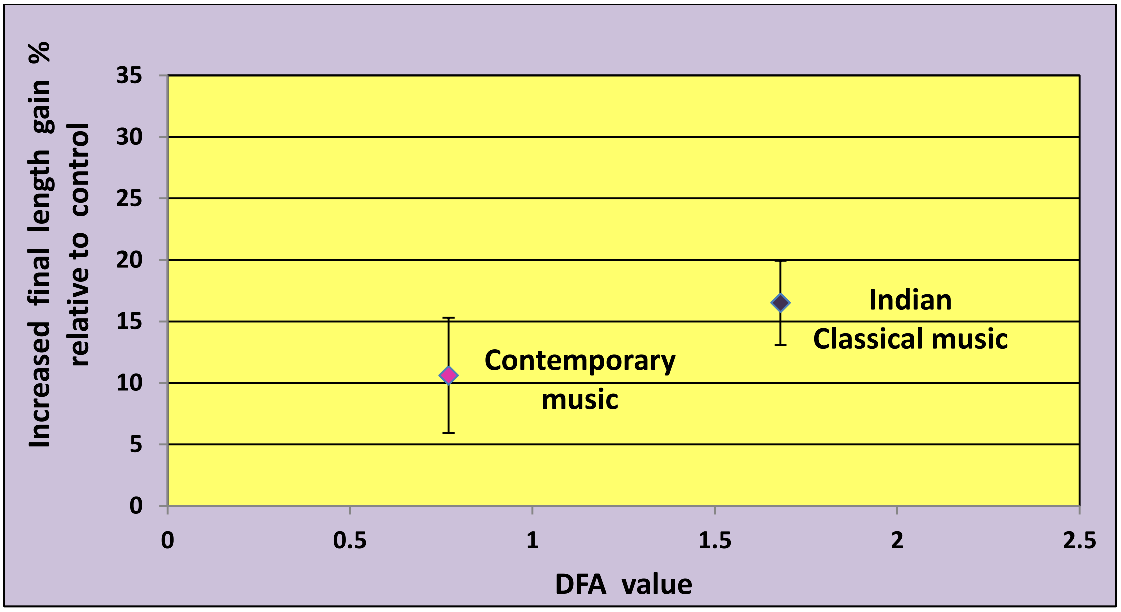


Fig.8.11: Graph comparing increased final length gain % of two different kinds of music stimulated fish groups over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

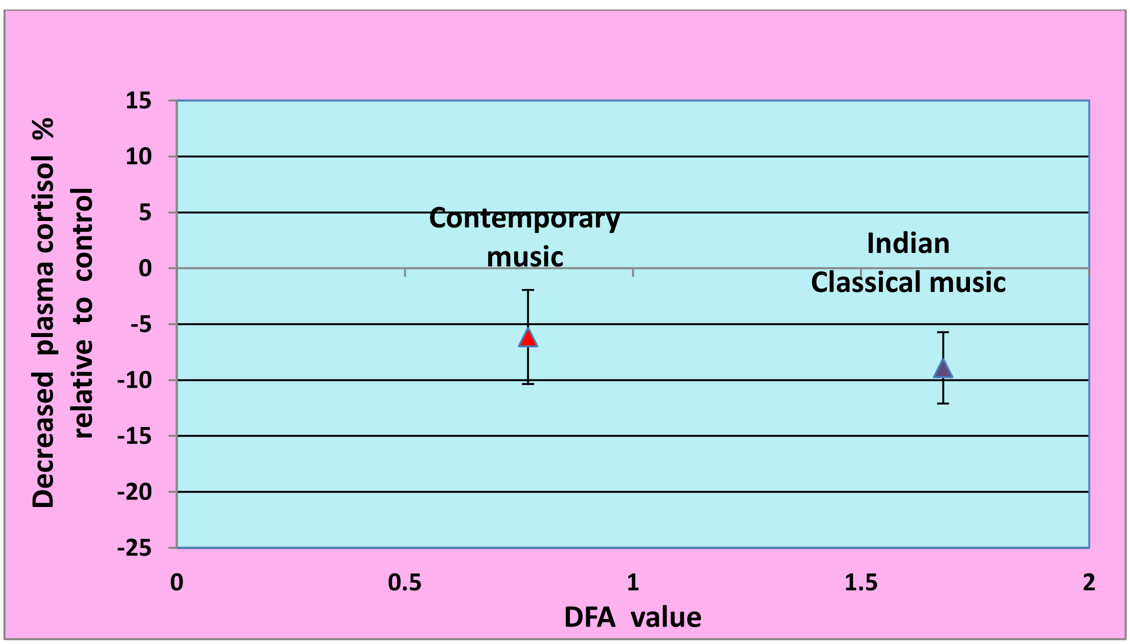


Fig.8.12: Graph comparing decreased % of plasma cortisol level of two different kinds of music stimulated fish groups over control versus DFA values of two music signals (Vertical bars represent mean ± SD)

8.5 DISCUSSION

In this present study, the effects of auditory environmental enrichment via Indian Classical and Contemporary music exposures on Nile Tilapia fish have been examined. The results reveal positive effect of music in fish growth consistently throughout the experiment. It is also apparent that the Indian Classical music treated fish group experienced better growth than Contemporary music treated group. Not only better growth, relieved stress response was also achieved through music treatments with reduced plasma cortisol levels.

Therefore, the efficiency of using music to improve growth and stress physiology in Nile tilapia has revealed in this study. As cortisol measurement has long been an excellent approach to find out the stress levels in fishes, the magnitude of the cortisol response represents a suitable parameter for the comparative goal of the present study. Thus musical "auditory" environmental enrichment can be useful to promote growth and welfare in Nile tilapia and therefore has the potential to meet the raised demand for Tilapia fish production through sustainable expansion of aquaculture. Hardly till date there is any report revealing the role of auditory environmental enrichment in terms of DFA scaling exponent of music signal in Nile Tilapia.

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CHAPTER 9

CONCLUDING REMARKS

9.1 CONCLUSION

This section presents the summary of results in Table no. 9.1 based on which one may draw the following interesting conclusions.

The Table in general shows the effect of music on seed, plant, and animal is significant and depends on music stimuli characterized quantitatively with the help of standard nonlinear parameter.

In case of seed, the Table 9.1.A speaks for itself. The amount of germination due to two kinds of music stimuli (Indian Classical and Natural) over the control is same; however Mean Germination Time (MGT) depends on nature of music. These are the results for the first sample *Pisum sativum*.

In case of second sample *Cicer arietinum* differences has been found both in the amount of germination and Mean Germination Time due to the above mentioned music stimuli relative to control, indicating that plant species is also important for music induced germination.

In case of plant, the Table 9.1.B clearly indicates that both plants have highest growth in case of Indian Classical music, the lowest in case of Epic Horror music. In this context, as shown in chapter 7 that in case of Epic Horror music initially plant growth decreases with time (up to 288 hours in case of *Pisum* and upto 240 hours in case of *Cicer*) and then it increases. This is an interesting observation and deserves special mentioning. However for Natural and Contemporary music difference of growth is also significant (considering standard deviation) but the amount of difference is less and this behaviour is seen for two types of plants.

We used two types of music input (Indian Classical music and Contemporary music) in case of fish. All the parameters – Weight gain %, Specific growth Rate %, final length gain %, and plasma cortisol level clearly shows the positive effect of music (Table 9.1.C). Also the result favours the idea that nature of music affects the growth in appreciable way.

This is further confirmed by the data of cortisol secretion with music. In case of fish also Indian Classical music takes over Contemporary music.

For convenience we have further included Fig. 9.1 showing how these parameters change with the complexity in terms of DFA of the music signal.

Table 9.1: Summary of experimental results A. Seeds B. Plants C. Fish

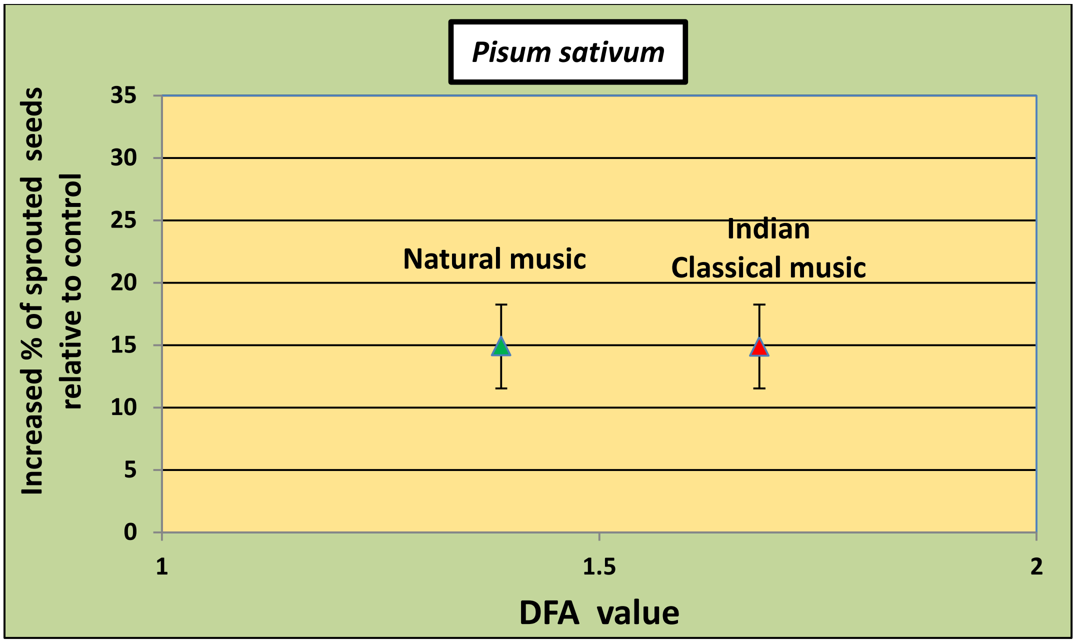
A. Seeds					
Sample	**Conditions**	**Mean Germination Time (Hour)**	**Amount of Germinated seeds**	**Decrease of Mean Germination Time (%) relative to control**	**Increase of amount of germinated seeds (%) relative to control**
Pisum sativum	1) Indian Classical music input	42.5	240	18.3%	14.9%
	2) Natural music input	45.3	240	13%	14.9%
	3) Control	52.07	209	—	—
Cicer arietinum	1) Indian Classical music input	52.3	240	7.6%	29.8%
	2) Natural music input	54	218	4.6%	17.9%
	3) Control	56.6	185	—	—

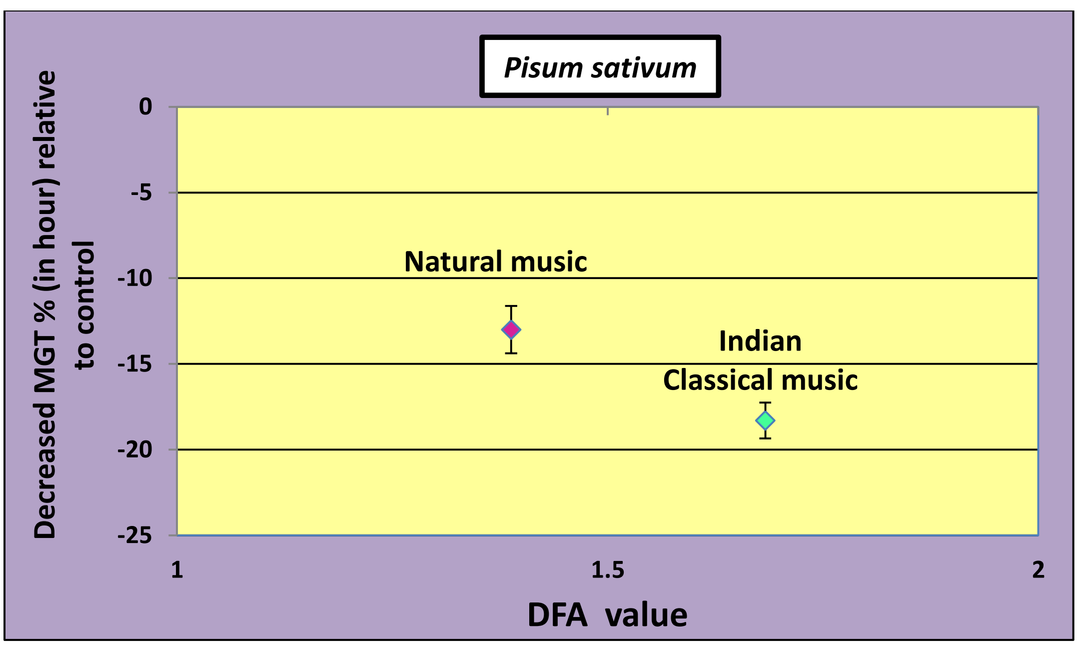
B. Plants			
Sample	**Conditions**	**Plant growth (cm.)**	**Increase of plant growth (%) relative to control**
Pisum sativum	1) Indian Classical music input	34.8	38.09%
	2) Natural music input	32.4	28.5%
	3)Contemporary music input	31.4	24.6%
	4) Epic Horror music input	25.6	1.5%
	5) Control	25.2	——
Cicerarietinum	1) Indian Classical music input	35.5	40.8%
	2) Natural music input	32.8	30.1%
	3)Contemporary music input	30.02	19.1%
	4) Epic Horror music input	25.6	1.5%
	5) Control	25.2	——

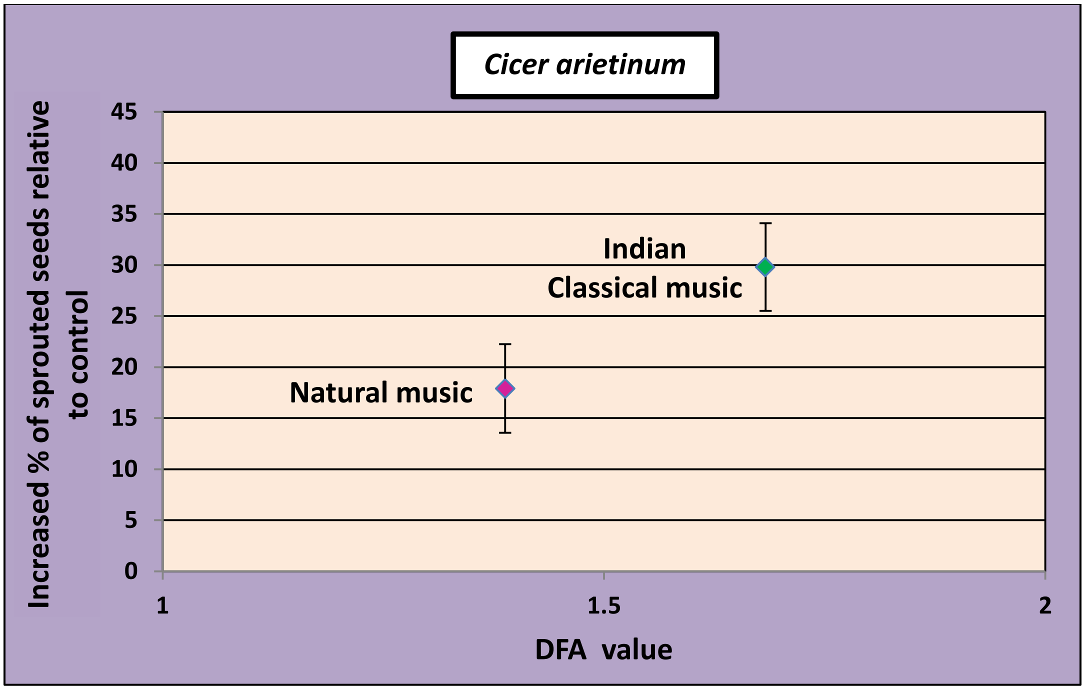
C. Fish			
Conditions	1) Indian Classical music input	2) Contemporary music input	3) Control
Weight Gain (gm.)	36.21	34.21	29.12
Specific Growth Rate	0.87	0.86	0.77
Final length Gain (cm.)	14.3	13.57	12.28
Plasma cortisol level (ng/ml)	27.87	28.73	30.63
Increase of Weight Gain (%) relative to control	39.9%	28.6%	——
Increase of (%) Specific Growth Rate relative to control	22.4%	16.6%	——
Increase of final length Gain (%) relative to control	16.5%	10.6%	——
Decrease of plasma cortisol concentration (%) relative to control	8.9%	6.1%	——

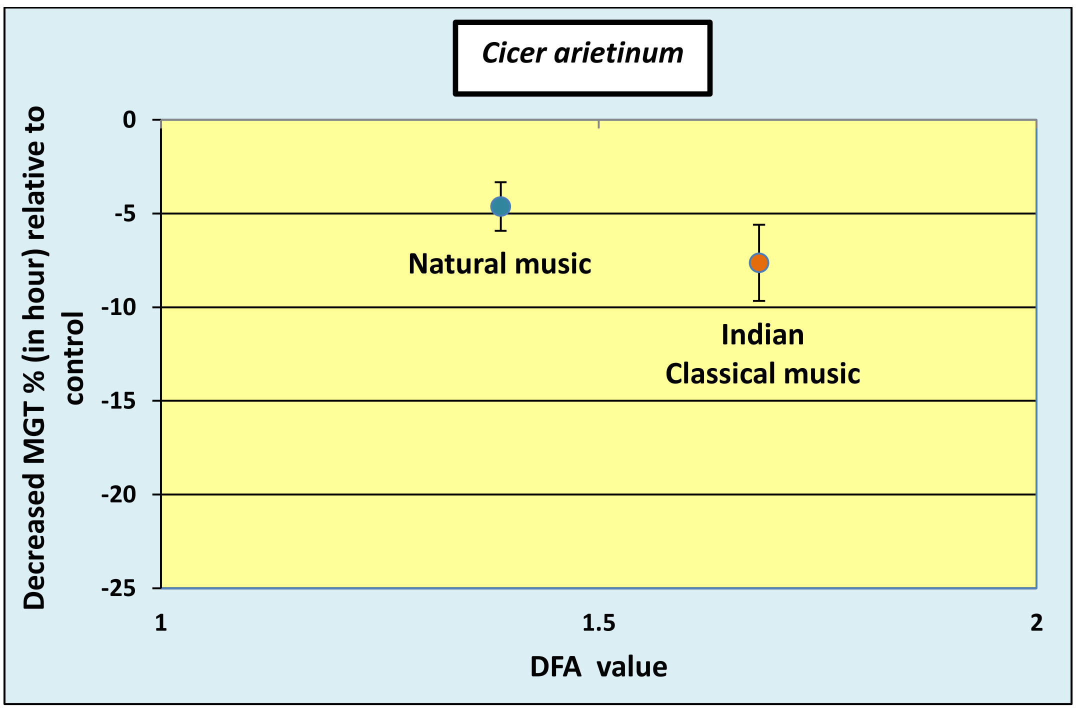
Fig. 9.1: Parameter differences relative to control with complexity in terms of DFA of the music signals A. Seeds B. Plants C. Fish

A. Seeds

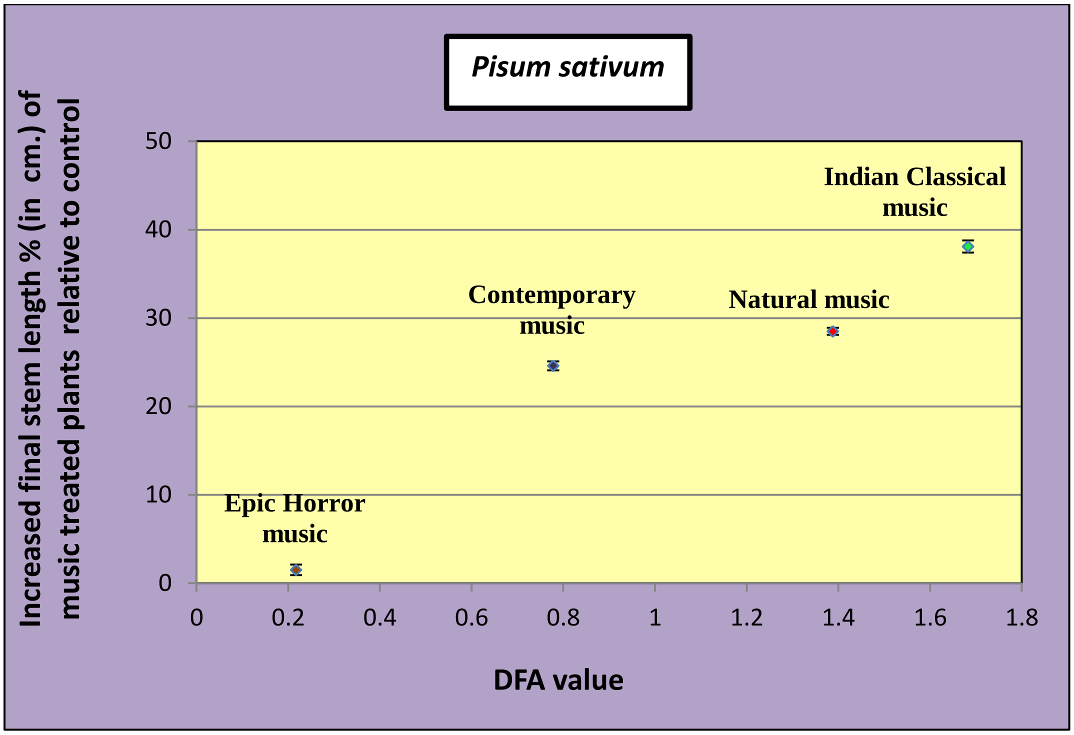




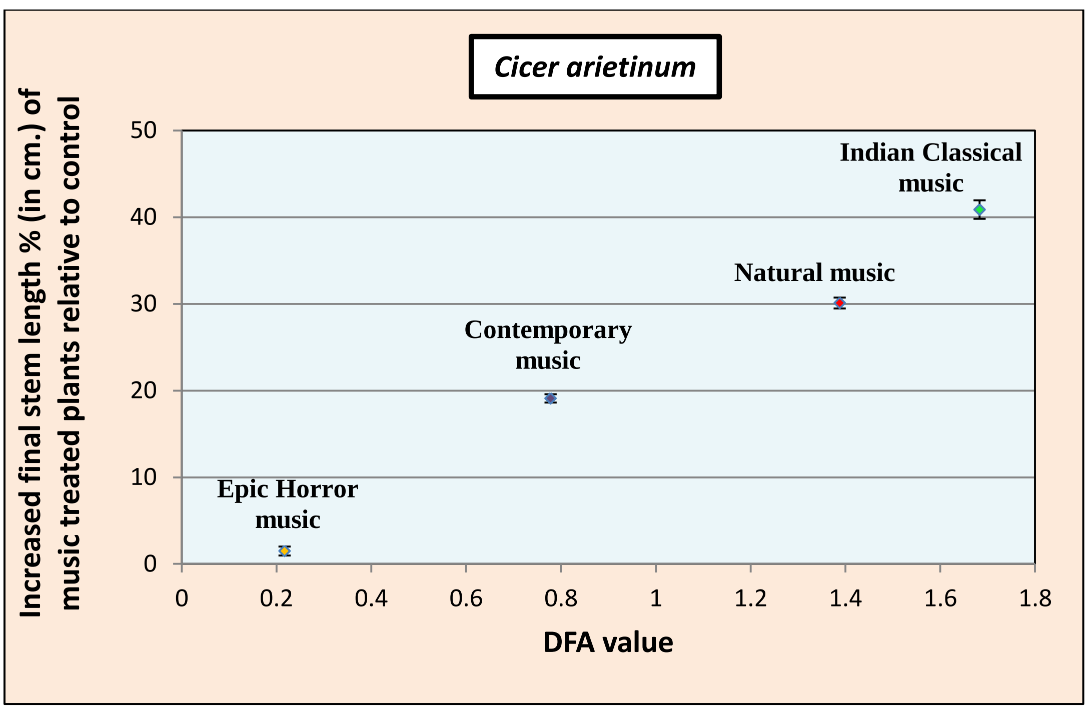

Cicer arietinum
Increased % of sprouted seeds relative to control
45
40
35
30
25
20
15
10
5
0
Indian
Classical music
Natural music
1
1.5
2
DFA value


Cicer arietinum
Decreased MGT % (in hour) relative to control
0
-5
-10
-15
-20
-25
Natural music
Indian
Classical music
1
1.5
2
DFA value

B. <u>Plants</u>

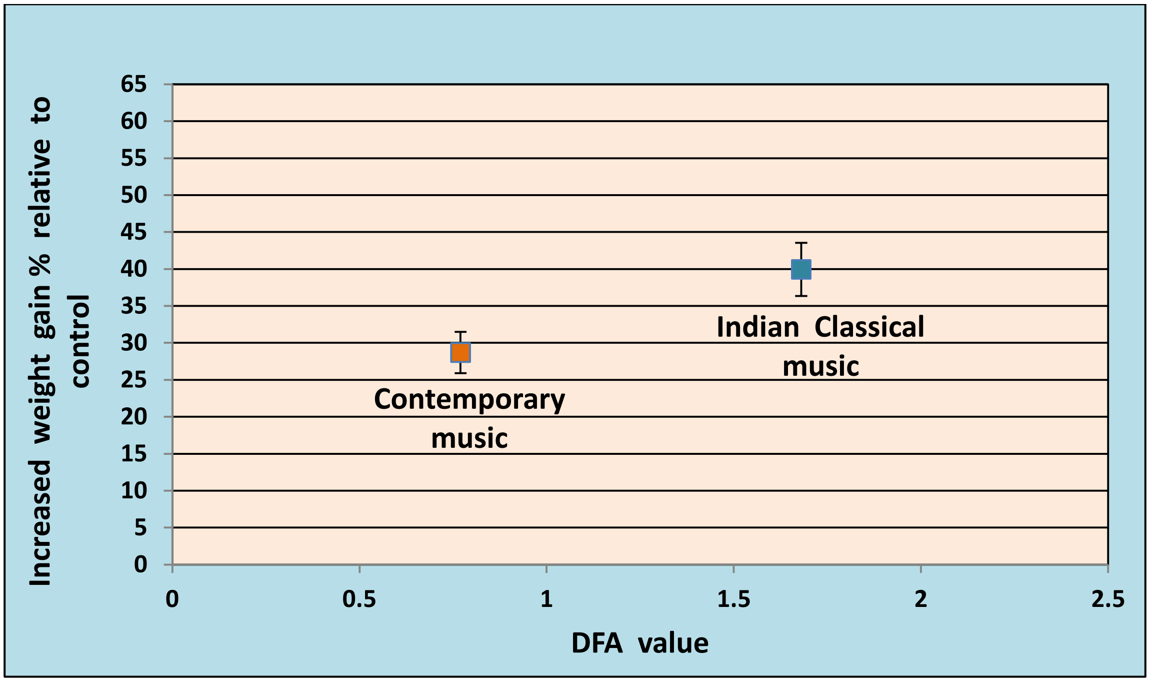


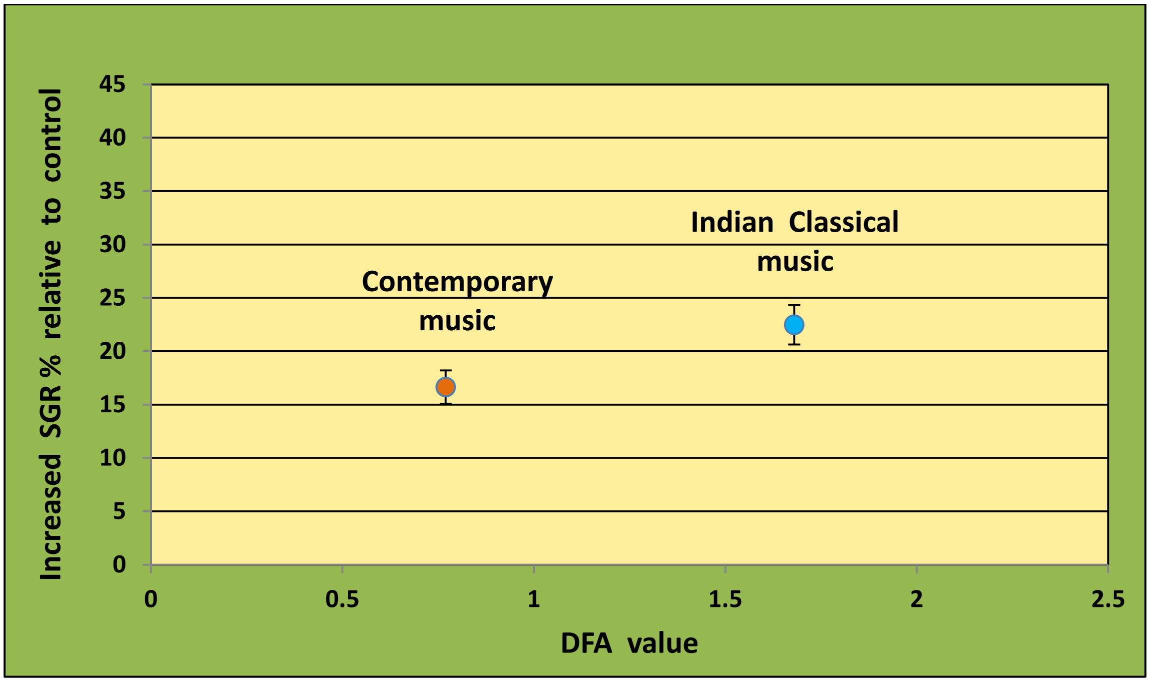
Pisum sativum
Increased final stem length % (in cm.) of music treated plants relative to control
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
DFA value
Indian Classical music
Contemporary music
Natural music
Epic Horror music

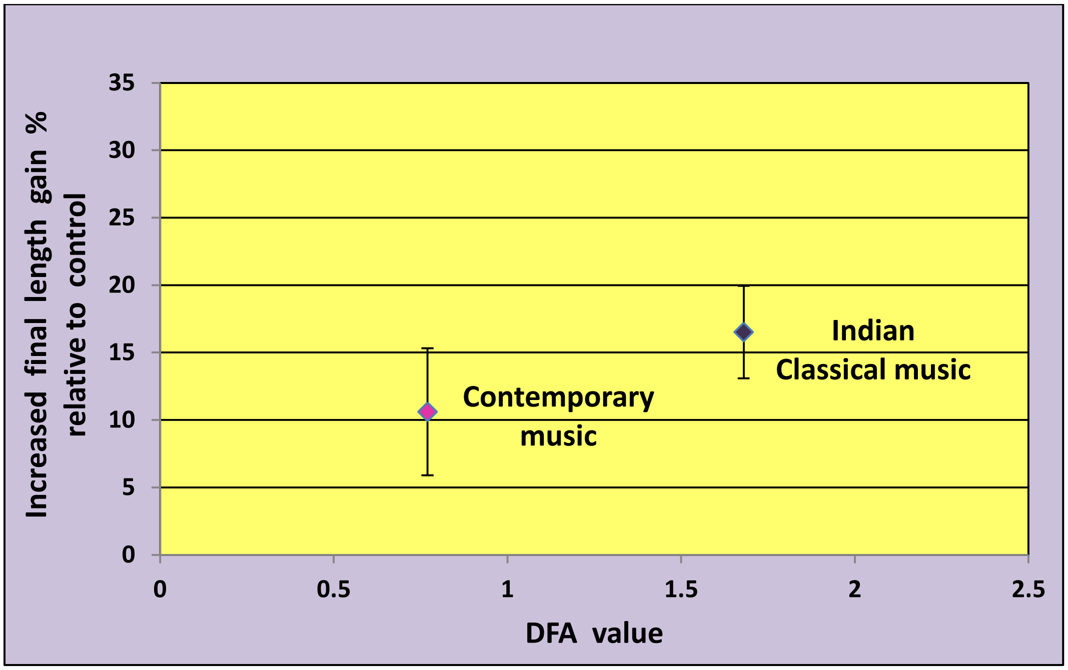


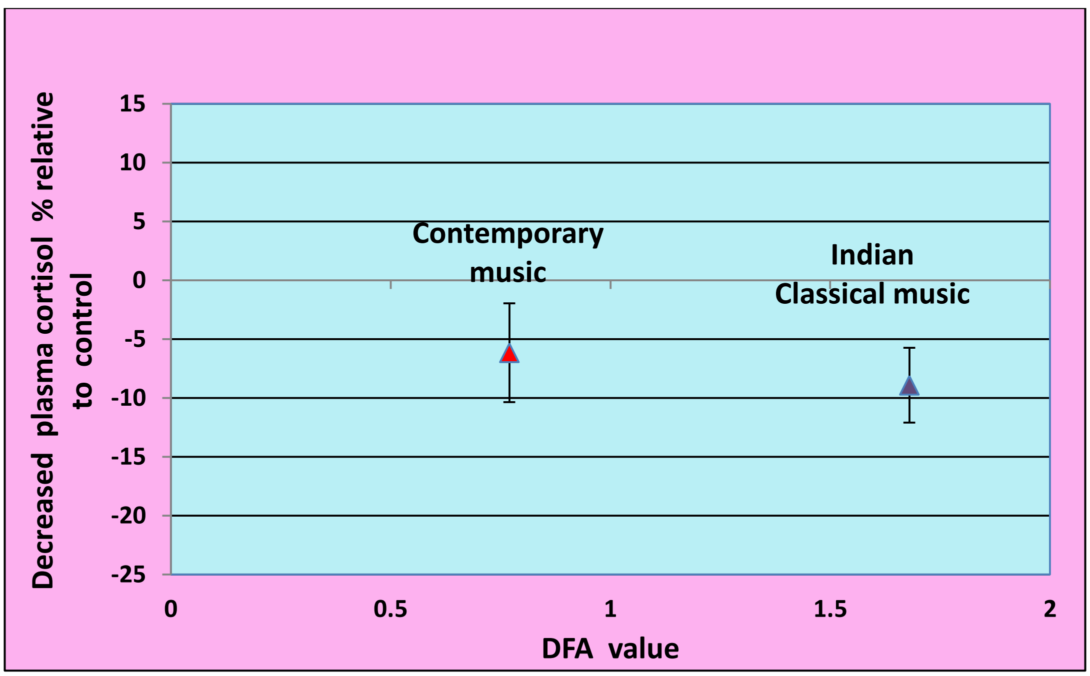
Cicer arietinum
Increased final stem length % (in cm.) of music treated plants relative to control
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
DFA value
Indian Classical music
Natural music
Contemporary music
Epic Horror music

C. Fish


Increased weight gain % relative to control
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
DFA value
Contemporary music
Indian Classical music


Increased SGR % relative to control
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
DFA value
Contemporary music
Indian Classical music


Increased final length gain % relative to control
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
DFA value
Contemporary music
Indian Classical music


Decreased plasma cortisol % relative to control
15
10
5
0
-5
-10
-15
-20
-25
0
0.5
1
1.5
2
DFA value
Contemporary music
Indian Classical music

This investigation clearly manifests that the growth parameters of plants and animals due to input of different kinds of music stimuli positively depend on the composition of music input parameterized in terms of DFA scaling exponent.

This pioneering work will stimulate further work in this domain considering more samples of plants and animals and also with different genre of music possessing varied degree of complexity.

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