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Tree Dielectric Response as an Earthquake Forecasting

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Abstract

Seismic precursor identification is vital in the Himalayan range and near active fault lines to offer early earthquake warnings, as India and nearby areas face a high risk of seismic activity. This laboratory-based research conducted simulations aimed at replicating electromagnetic signals generated by artificial seismic events spanning frequencies from 1 Hz to 59 Hz. High-frequency seismic signal attenuation upon interaction with the Earth's surface was observed, focusing on emulating electromagnetic waves within the ultra-low frequency (ULF) to very high frequency (VHF) range and investigating energy transfer dynamics within conductive materials. Findings included a reduction in green stem ring diameter, an inversely correlated penetration depth with frequency, and fluctuations in the dielectric constant of tree tissues, linked to water molecule polarization with frequency changes. By applying an electric field, lower dielectric constants were observed at lower frequencies, stabilizing at around 40 eV as frequency increased from 1 Hz to 59 Hz. As frequency levels escalated, especially transitioning into the radio or microwave spectrum, alterations in the dielectric constant of tree tissues were noted, often marked by an increase in dielectric loss, signifying heightened absorption of electromagnetic energy and its conversion into heat. Banyan tree roots exhibited responses well in advance of any discernible alterations in the subsurface environment, offering valuable early indicators of impending seismic activity. This discovery encourages further exploration and holds the potential to advance earthquake prediction using deep-rooted trees as biosensors, ultimately contributing significantly to the preservation of human lives and overall safety.

Keywords: Biosensors, Dielectric Constant, Precursors, Seismic Activities, Ultra-Low Frequency.

Introduction

Natural disasters pose significant challenges, particularly in predicting and mitigating their impacts. Understanding the precursors to such events is crucial for developing effective early warning systems. These systems can provide timely alerts, potentially saving lives and reducing damage caused by earthquakes, landslides, and other natural disasters. Such type of research involves a comprehensive investigation into the response patterns exhibited by environmental variables and ground motion signals, particularly in the context of seismic events and landslides. Notably, trees themselves serve as live sensors due to their inherent conductive properties for electromagnetic signals. These signals offer insights into the processes occurring deep within the Earth's crust, such as fault movements and stress accumulation. The impact of electromagnetic signals generated by earthquakes on the xylem and phloem of tree rings is a complex and relatively unexplored area of research. Understanding geomorphic processes and having knowledge of past events are crucial for assessing natural hazards. Previous studies have demonstrated that extremely low-frequency (ELF) and ultra-low-frequency (ULF) seismic signals can propagate over long distances through the Earth's middle crust. Certain plant species, such as *Mimosa pudica*, Venus flytraps, Banyan trees, and Kail pine trees, which are deep-rooted and long-lived, have shown heightened sensitivity to electrical signals. These plants are capable of detecting subtle environmental changes, and therefore, may serve as bio-indicators of seismic activity. Various natural sensors, such as changes in animal behaviour, oil wells, hydro-chemical precursors, radon gas emissions, and water level fluctuations, have been studied in earthquake research, but Banyan trees offer unique advantages as seismic bio-indicators. Unlike animal behaviour, which is difficult to track consistently, the Banyan trees provide continuous, passive environmental monitoring through their deep-rooted systems, interacting with subsurface layers over time.

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They naturally respond to changes in soil's dielectric properties caused by seismic stress without requiring human intervention, making them low-maintenance. Their long lifespan allows them to gather data across multiple seismic events, unlike radon levels or water fluctuations, which vary seasonally. Banyan trees are also widely available in seismically active regions in India, offering a more accessible alternative compared to oil wells or radon detectors. Their sensitive root networks interact with underground structures, detecting shifts that other sensors may miss. Banyan trees improve seismic monitoring by serving as natural, low-cost supplements to traditional sensors, particularly in areas without advanced infrastructure. Thus, their biological sensitivity and long-term adaptability make them valuable for earthquake research. Tree rings have often demonstrated their reliability in providing data on historical events. The use of tree rings in natural hazards research, beginning with a description of various disturbances caused by geomorphic processes and the resulting growth reactions. These disturbances include hydrological processes like flooding and debris flows, as well as mass-movement processes such as landslides and snow avalanches (1). Tree rings, those concentric circles that adorn the cross-section of a tree trunk, have long been recognized as a valuable source of information about a tree's life history, but their potential as a tool for studying past seismic events has only recently gained attention. Researchers have discovered that the growth patterns of trees can be influenced not only by climate but also by the physical stresses imposed by earthquakes, providing a unique window into the past (2). The impact of volcanic activity on tree ring structure at the Tacana volcano, located on the Mexico-Guatemala border motivated to deeply analyze the changes occurred before and after the seismic event (3). One of the key benefits of using tree rings as a proxy for earthquake evidence is their ability to extend the historical record far beyond the limits of written records (4). For instance, the response of tree rings to the Hebgen Lake earthquake (1959), with a magnitude of 7.5, which occurred along a normal fault in the Gallatin National Forest in southwestern Montana, demonstrated a correlation between changes in tree rings and seismic events (5). An analysis of tree rings from 'kail' pine in Uttarkashi, Western Himalaya, was conducted to assess the impact of the 1991 earthquake. The study revealed that the tree rings were observed narrower in 1992, the year following the earthquake (6). Similar findings were observed in studies conducted in the Patagonian Cordillera (7). The eastern Tibetan Plateau, where reductions in tree ring width occurred immediately after significant earthquakes (8). These studies indicate that trees near active fault zones can detect seismic signals before the earthquake itself. Tree radial growth is influenced by both climatic and non-climatic factors like seismic events, complicating the extraction of climate signals from tree rings It is found that disturbances impacted on tree ring (9). It is essential to understand the impact of electromagnetic signals at normal environment condition. Electromagnetic signals in the Extreme-Low-Frequency (ELF) and Ultra-Low-Frequency (ULF) range can be associated with geological and environmental processes. Changes in the Earth's crust and subsurface, such as fault movements and stress accumulation, can generate electromagnetic signals. High-frequency signals do not penetrate deep into the Earth's crust because they have shorter wavelengths, which are absorbed or reflected by surface layers. These signals tend to dissipate quickly and are more easily obstructed by materials like soil and rock. In contrast, low-frequency signals, such as extremely low frequency (ELF) and ultra-low frequency (ULF) waves, have longer wavelengths that allow them to travel through dense materials and reach deeper layers where tree roots, like those of Banyan trees, can detect changes in soil properties. This makes high-frequency signals less effective for detecting deep subsurface seismic activity or interacting with the deep root systems of trees. Extremely low frequencies (ELF) and ultra-low frequencies (ULF) penetrate deep into the Earth's crust, where they can interact with the deep roots of trees. These roots are sensitive to changes in the soil's dielectric properties, which are influenced by seismic activity. Trees, particularly with extensive root systems like Banyan trees, can detect these shifts due to their natural electrical potentials, making them more reactive to lower-frequency waves compared to higher-frequency ones that don't penetrate as deeply. During an earthquake, a tremendous amount of energy is released, which can be quantified in units like joules or calories. The amount of released energy is directly related to the earthquake's magnitude (10). Researchers use specific formulas to calculate the total energy released during an earthquake, which helps in understanding the event's intensity and potential impact.

$$E = 10^{(1.5M+4.8)} \quad [1]$$

Where:

- E is the seismic energy release in joules (J).
- M is the magnitude of the earthquake measured on a logarithmic scale

The magnitude (M) is measured on a logarithmic scale, meaning small increases in magnitude correspond to significant increases in energy release. It is important to note that the energy released during an earthquake is mostly in the form of seismic waves, which propagate through the Earth's crust and can cause ground shaking and structural damage. The destructive potential of an earthquake depends not only on its magnitude but also on factors like depth, distance from the epicenter, and local geological conditions. Within this context, it is essential to consider the dielectric constant as a measure of the electrical energy storage capacity. Additionally, the transformation of electromagnetic energy into thermal energy is evaluated through the concept of dielectric loss. The study of dielectric properties pertaining to Banyan trees is undertaken to gain insights into various aspects, including the molecular structure of trees, interactions between wood and water, as well as the density and moisture content within trees. That's why the dielectric properties of the tree roots are important and are strongly influenced by the gravimetric moisture content. The gravimetric moisture content of a tree is directly proportional to the dielectric characteristics of the tree root (11,12). The moisture content within tree branches experiences seasonal fluctuations, thereby influencing their time-dependent dielectric properties. It is imperative to investigate alterations in the dielectric characteristics of deeply rooted trees under both normal conditions and high-energy signal states. This scrutiny is especially relevant because seismic events unleash substantial energy during earthquakes. Harnessing the extensive lifespan of deep-rooted trees as a potential precursor indicator for seismic events is another significant aspect of this research orientation (13). Furthermore, it's worth noting that in 1994, the electrical potential of trees was identified as a precursor phenomenon during the Miyagi offshore earthquake (14). India is located in a seismically active zone due to its position on the boundary of the Indian plate and the Eurasian plate. The Himalayan region, in particular, is highly prone to earthquakes. To study seismic precursors, researchers often monitor ground deformation, changes in groundwater levels, and electromagnetic signals as potential indicators of impending seismic events. India indeed has a diverse and heterogeneous geography and environment, making it a region of interest for various geological and environmental studies, including the identification of precursors for seismic events, landslides, and the associated electromagnetic signals in the ELF and VLF range (15). In India, certain long-lived trees such as Banyan, Pipal, and Devdar have thrived for centuries. Conducting tree ring analysis on these trees holds the potential to unveil precursor indications of seismic activities (16). The combination of deep-rooted nature, ability to sense dielectric shifts, and historical evidence of tree responses to seismic events, banyan trees dielectric response can be used in earthquake forecasting particularly in Himalayan high seismic region. This research paper examines the dielectric properties of deep-rooted, old-aged Banyan trees through tree ring analysis under normal environmental conditions and electromagnetic signals. The aim is to explore the potential of using these trees as bio-sensors to detect seismic activity. For investigation, both a deep-rooted Banyan tree and a normally rooted Ashok tree were selected. Studying biosensors like trees in the context of earthquakes is not a conventional approach, as trees are not typically used to forecast or detect seismic events directly. However, there are indirect ways in which the study of trees and other biosensors can provide valuable information related to earthquakes and their effects. The low frequency electromagnetic ground waves generated by natural disasters such as seismic events and landslides are absorbed by these deep-rooted trees, leading to structural alterations in their tree rings. The study involves a comprehensive tree ring analysis to gain insights into the dielectric properties and electrical potential acquired by Banyan trees, effectively utilizing them as bio-potential sensors. The dielectric properties of tree rings were examined under normal conditions and when exposed to high-energy signals at normal room temperature. The electromagnetic emissions simulated in the laboratory have demonstrable effects on the growth ring structure of deep-rooted trees. Seismic events serve as a source of electromagnetic waves, and these wave signals are intercepted by the xylem and phloem cells within deep-rooted trees, leading to consequential alterations in their internal ring structure. This phenomenon aligns with previous studies conducted in Japan (17-19).

Methodology

Ions within tree biomass become electrically charged when exposed to electromagnetic emissions. When these emissions encounter the latex, the dielectric material's randomly oriented dipoles align themselves in opposition to the external electric field. This alignment results in energy absorption and its storage as potential energy within the molecule. The kinetic energy generated by ionic conductivity and dipole rotation is then transmitted through the green stem and propagated into the Earth's surface (20-22). To investigate the dielectric properties of latex, green stems from both deep-rooted Banyan and shallow-rooted Ashok trees, with and without bark, were used. A Hioki LCR Meter (IM3533), which measures inductance (L), capacitance (C), and resistance (R), was employed to assess key dielectric characteristics such as permittivity, impedance, and dielectric loss, all at room temperature. The LCR meter operates in a frequency range of 0.1 Hz to 3 GHz. The LCR meter is equipped with a dielectric sensor to investigate the dielectric properties and an electromagnetic wave generator (Figure 1). Continuous measurements were taken at a sampling rate of 60 samples per second to capture any sudden changes in dielectric properties. When a signal is applied to the Banyan latex, it gives an impedance response in the frequency range of 0.1 Hz to 60 Hz. At higher frequencies, the impedance becomes constant, a phenomenon known as tangent loss. Tangent loss helps quantify the inefficiency of a dielectric material in storing and transmitting electric energy. The dielectric behaviour of latex is an important parameter for identifying seismic conditions and is useful in the potential early warning systems for earthquakes. At lower frequencies, the dipoles in the material align with the changing electric field. As the frequency increases, the dipoles are unable to reorient, affecting the material's dielectric response.

Figure 1: LCR Meter (IM3533) for Analysis of Dielectric Property Analysis

To investigate the impact of electromagnetic emissions on tree ring structure, the tree stem underwent a steam bath, ranging from room temperature to 100°C for approximately 40 minutes. Following this, an in-depth analysis of the ring structure was conducted using electronic microscopy (Microscope model-Motic BA400). To support the findings on tree ring structure, an analysis of real-time bio potential data was carried out from a bio potential sensor installed in an old-aged Banyan tree situated on the campus of Hindustan College of Science and Technology, Mathura, India (latitude 27.2° N, longitude 77.7° E), in close proximity to the active Dehradun-Faridabad Belt (DFB), connected to the Main Boundary Fault (MBF) as shown in Figure 2 based on research paper published by Prakash R and Shrivastava JP (23).

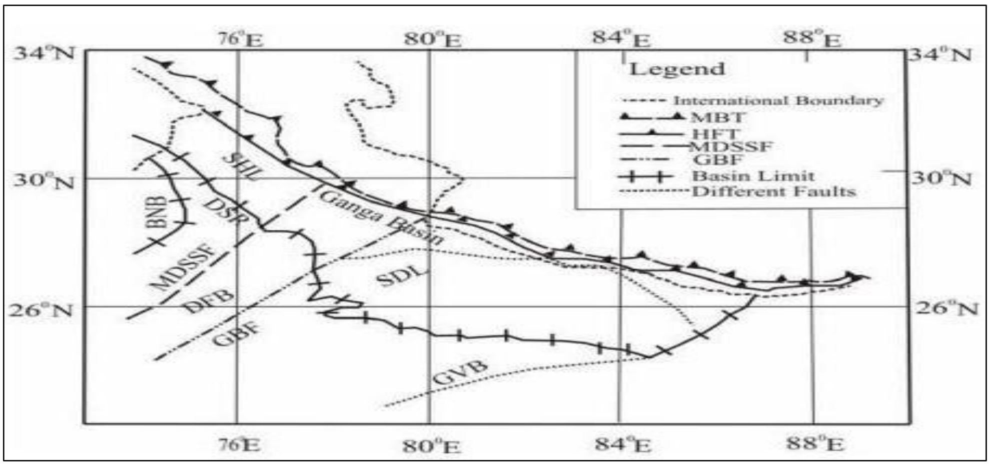

Figure 2: Tectonic Structure of the Himalaya Thrust Fault Belt and Active Fault Belts (23)

Results and Discussion

In the laboratory, electromagnetic signals were simulated using a low-frequency generator spanning from 1 Hz to 59 Hz. Notably, seismic high-frequency signals tend to experience attenuation at the Earth's surface. This phenomenon, observed in the very low frequency range, including ELF to VLF frequencies, has been replicated to demonstrate the transfer of energy into conducting materials (24,25). In the frequency range of 1 Hz to 59 Hz, it is observed a relative relationship between frequency and the dielectric constant for both Banyan and Ashok tree latex. As depicted in Figure 3, the dielectric constants of Banyan and Ashok trees with bark were higher compared to those without bark.

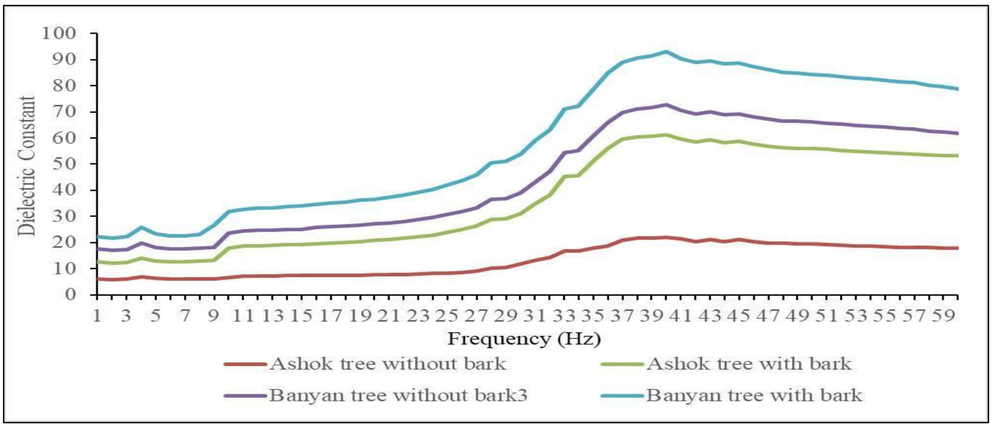

Figure 3: Dielectric Constant Measurement across Frequencies for Banyan and Ashok Trees

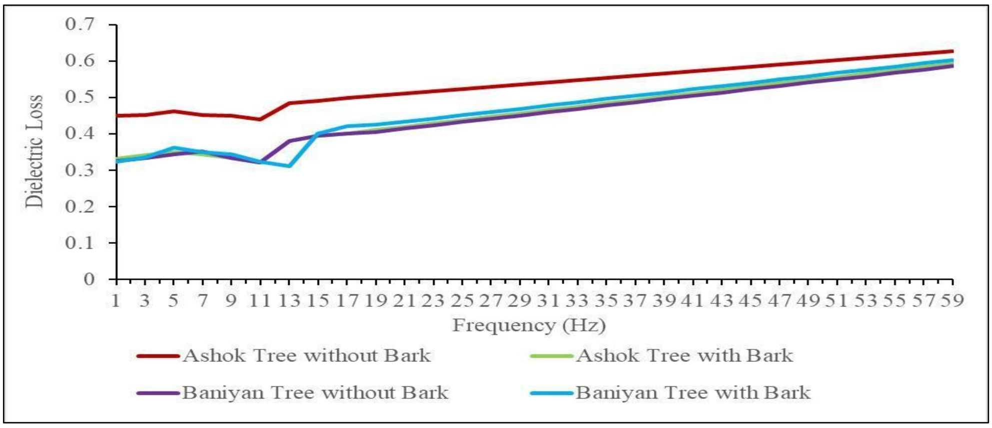

Figure 4: Frequency-Dependent Dielectric Loss Analysis of Banyan and Ashok Tree

Interestingly, as the frequency increased, there was a gradual reduction in dipole moment within the biomass. A saturation condition has been observed in the dielectric constant of the bark of

Banyan trees occurred between 30-40 Hz. This pattern indicates that Banyan and Ashok trees exhibit a steady increase in dielectric loss at higher frequencies as shown in Figure 4. Consequently, the deep-rooted barked Banyan trees have a greater capacity to store potential energy as the frequency increases as compared to normal rooted Ashok tree. The green stems of deep-rooted bared Banyan tree ring have shown a reduction in size, and it is noted that the penetration depth is inversely related to the observed higher frequencies. This relationship has been expressed through equations 2 and 3, demonstrating the stem's ability to store potential energy as the frequency increases, as depicted in Figure 3.

$$\delta = \sqrt{2/\omega\mu\sigma} \qquad [2]$$

$$\alpha = \frac{1}{\delta} \qquad [3]$$

Where
δ = skin depth (penetration Depth)
w = frequency
μ = refractive index
σ = conductivity
α = attenuation constant

A comprehensive examination of stem properties was carried out using a high-resolution electronic microscope with 40x zoom capabilities. It observed that the relaxation time in both bark and unbark Banyan trees changes with frequency, suggesting that at higher frequencies, the realignment of xylem and phloem becomes impossible. Furthermore, the findings suggest a gradual decrease in impedance as frequency increases as shown in the Figure 5.

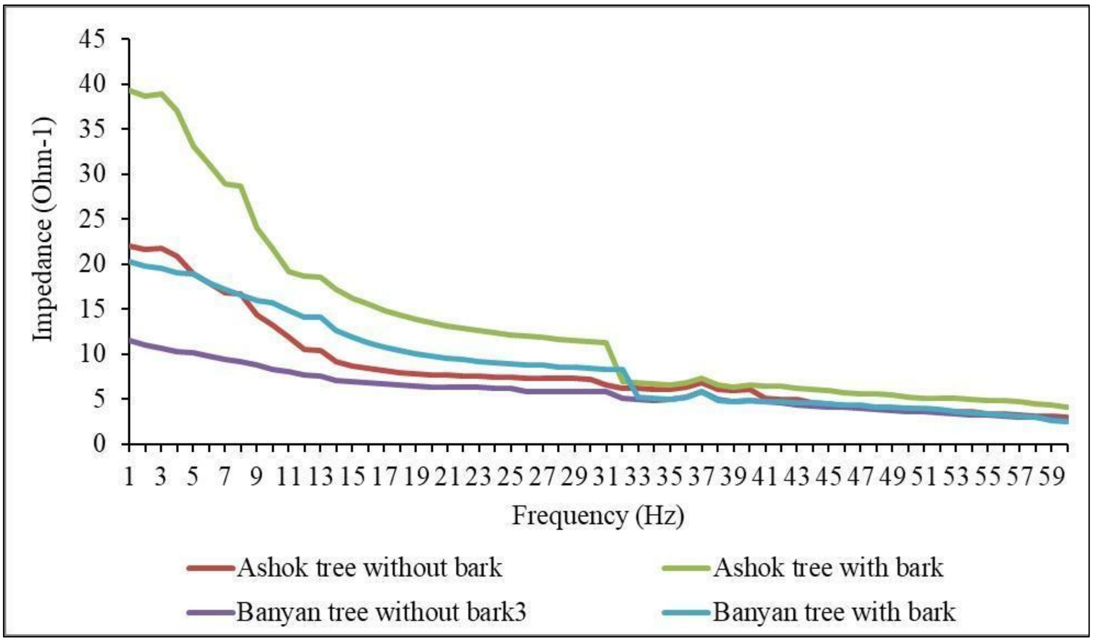

Figure 5: Impedance Measurement across Frequency Spectrum for Banyan and Ashok Trees

The Banyan and Ashok trees exhibit a robust frequency response within the dielectric constant range of 1 to 40 Hz. Notably, old-aged Banyan trees possess a higher capacity for electric charge storage compared to other tree species like Ashok tree, with this ability diminishing as frequency increases. The sub harmonic frequencies, particularly within the ELF range, bear resemblance to precursor signals of seismic events like earthquakes (26). These waves have a depleting effect on the latex within Banyan trees and influence the concentration of xylem and phloem in these trees. As illustrated in the Figure 6(A), the phenomenon of phloem within stem cells of Banyan tree becomes evident under natural conditions, observed using a high-resolution electronic microscope at 40x zoom, revealing changes in the ring structure and xylem content within the internal cell structure. To validate changes in the dielectric characteristics of Banyan trees, a comprehensive study was conducted by recording and cross-referencing ground motion data using a bio potential sensor and environmental noise data via a terrestrial antenna, both strategically positioned at HCST, Farah, India (Latitude 27.2° N, longitude 77.7° E). This research indicates a clear correlation between changes in the dielectric properties of these deep-rooted

Banyan trees and fluctuations in ground motion. A steam bath was administered within the temperature range of 60–100 °C for duration of 40 minutes. As the temperature gradually increased, noticeable shrinkage of the Phloem within the cell structures was observed, as shown in Figure 6(B). Figure 6(C) shows the micro scale view (scale 100μm). At the onset of seismic events, tree rings undergo a contraction process and do not recover their initial form, primarily because they absorb high-energy signals. These transformations in the ring structure represent a significant and predictive indication of impending seismic activity. The utilization of a 40x microscope zoom enables a comprehensive examination of the tissues and cells within the stem, including the arrangement of vascular bundles, cortex cell patterns, and various structural characteristics. This phenomenon, wherein the structure contracts due to high-energy impact, is prominently illustrated in Figure 6(B)

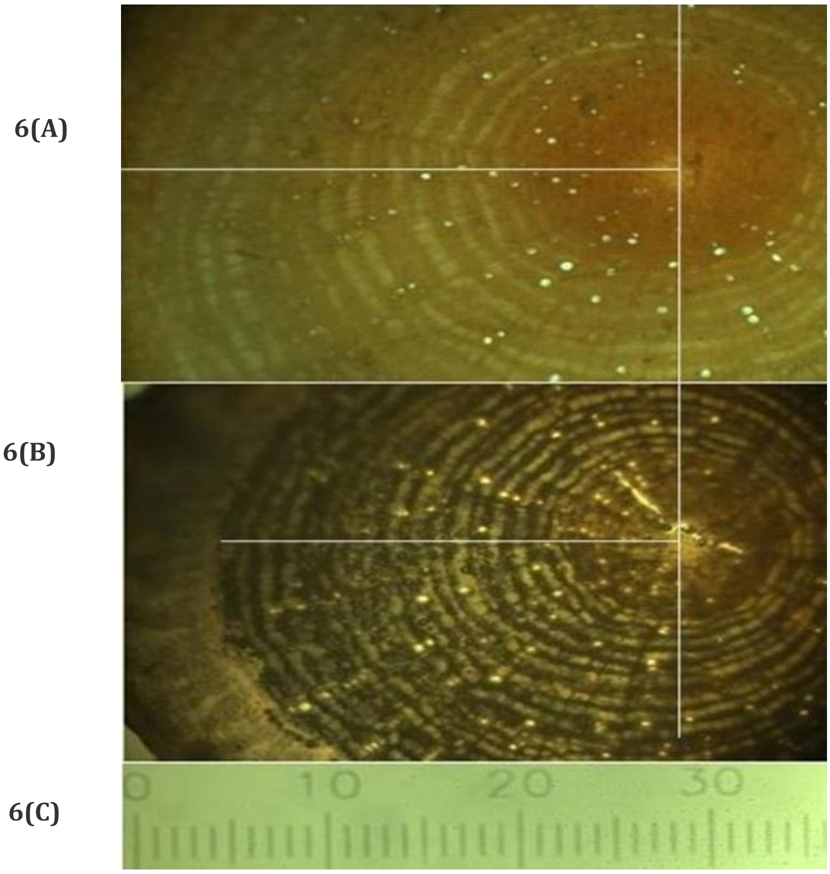

Figure 6: (A) Stem Cell Ring Structure of Banyan Tree at Room Temperature (36°C) at 40x Magnification (Scale 100μm)**;** (B) Stem Cell Shrinkage (Phloem) Structure at 100°C at 40x Magnification (Scale 100μm); (C) Micro scale View (Scale 100μm)

Conclusion

Low-frequency signals exhibit greater penetration depth and are detected by the biosensor with a lower potential difference. During seismic events occurring at shallow depths, both lower and higher frequencies are generated. If high energy electromagnetic signals are received by neighboring root sensor, it triggers changes in concentration and ring structure, serving as a valuable precursor to seismic activity. These phenomena can be comprehensively studied by continuously measuring potential differences in real-time. In seeking to draw a conclusive inference about the dielectric properties of deep-rooted and long aged trees in response to abnormal underground signals, such as electromagnetic waves, within proximity to fault regions. The tree roots exhibit a noticeable response period before any surface ground alterations, thus providing a clear and advanced indication of impending seismic activity. This intriguing finding necessitates further in-depth analysis, pointing us towards potential advancements in the realm of earthquake forecasting and prediction, with the ultimate goal of contributing to the preservation of human lives. Establishing a network of biosensor and monitoring stations across different regions of India is crucial for collecting data on seismic and electromagnetic signals. This data can be analyzed to identify patterns and anomalies that may serve as precursors to seismic events or landslides.

Abbreviations

DFB: Dehradun-Faridabad Belt, ELF: Extreme-Low-Frequency, LCR Meter: Inductance L, Capacitance C, and Resistance R meter, MBF: Main Boundary Fault, ULF: Ultra-Low Frequency, VHF: Very High Frequency.

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Author Contributions

Vijay Subhash Katta: Conceptualization, Data collection, Writing – original and final draft. Dr. Gourav Shrivastava: Supervision, revision of draft. Dr. Vinod Kumar Kushwah: Supervision, revision of draft.

Conflict of Interests

The authors declare that they have no conflicts of interest to report regarding the present study.

Ethics Approval

This research did not involve any human or animal subjects and therefore did not require ethics approval from an Institutional Review Board (IRB) or ethics committee.

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