Investigation of Radio Waves Effects on Tomato Plants

Chandni Upadhyaya, Trushit Upadhyaya, Hiren Patel, Ved Vyas Dwivedi, and Ishita Patel

Abstract Telecommunication systems are ever-expanding to meet the global requirement of always-on and faster communication. Cell towers and satellite communication-based communication facilitate such communication. The non-ionizing radiation from these cell towers providing 4G communication to users affects the plants in proximity. The tomato plant is extremely crucial from a commercial viewpoint; the present study provides an analysis of alterations occurring in tomato plants. The analysis consists of physiological and chemical perspectives. The plants were given continuous exposure to the non-ionizing continuously modulating 2300 MHz radio waves to assess various analysis parameters. Left-handed circular polarized waves for continuous exposure up to 120 h were given with the Helical Antenna for assessment of electromagnetic (EM) waves on tomato plants. The adverse effects were observed during the examination of the tomato plants for the exposure to non-ionizing radiation. The agricultural products may significantly get damaged to satisfy the communication requirements of the advancing technologies. The base stations should be kept away from the agricultural lands to protect the yield.

Keywords 4G Communication · Radio waves · Non-ionizing radiations · Environmental pollution

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T. Upadhyaya et al. (eds.), *Proceedings of International Conference on Artificial Intelligence, Communication Technologies and Smart Cities*, Lecture Notes in Networks and Systems 1533, https://doi.org/10.1007/978-981-96-9196-8_16

1 Introduction

Food intake of the human is adversely affected significantly due to substantial environmental pollution. There are a range of pollutants ranging from soil, water, and air to name a few. Another type of pollutant that can also be considered as a mutant to plant and plant yields is electromagnetic (EM) waves. The non-ionizing radio waves are known to crop pollutants. A significant quantum of research has been carried out on the adverse effect of the EM waves on plants, fruits, and farm yield [1–11]. It becomes vital for human beings to consume food that is not mutated in any form for a healthy life. In addition, due to an extremely hectic lifestyle, it is strongly recommended to have consumption of healthy food. The survey suggests that due to unhealthy food, a range of diseases such as cancer, Alzheimer's, diabetes occur [4]. The recommendations of the National Research Council suggest having multiple of vegetation and fruits on an everyday basis for improved personal health. This shall create the requirement for extensive production of quality crops. The consciousness of quality food is equally important for all the nation's citizens.

There is a sudden and continuous increase in mobile phone subscriptions. The nature of the communication has become very complex to supply fast data rates for varied use cases. Multimedia and gaming increases on-demand communication. This steep rise can be made easier through the increase in the number of communication towers. This increase in turn increases the presence of radio waves in the air. The farmers invariably adopt installing towers on their land to incentivize the space. The WHO and ITU suggest that such an increase in radio waves is severe as an air pollutant. The raised radio frequencies in the air fundamentally increase the fields in the surrounding space. However, it is to be noted that primarily non-ionizing radio waves do not possess high-quantum energy chunks which are responsible for atom ionization. The theory behind the absorbed energy being transferred within the living substances, viz., plant leaves and fruits is that the frequency of atom collisions increases. The increase in collision causes incremental heat within the living organism which is known as a thermal effect. There is substantial research on the effect of heat, frequency, power level, signal modulations and type on plants [12–16]. A big quantum of research has also focused on animal organisms. Figure 1 illustrates the conceptual drawing of exposure of EM waves on Tomato Plants for 4G communication frequencies. Plants are usually resistant to such environmental stress, however any possible degradation in tissues should be avoided to increase the crop quality.

Calcium is a critical messenger in the plant cell. It is responsible for the proper functioning of the cells. The calcium movement within the cells is also a major and critical event. The nucleic acid gets altered due to DNA damage and becomes a strong reason for affecting the metabolism of the plant. The low-intensity EM wave has also caused DNA alterations in wheat crops. A commonly utilized 900 MHz frequency affected wheat crops by forming micronuclei causing deterioration of plant cells [17].

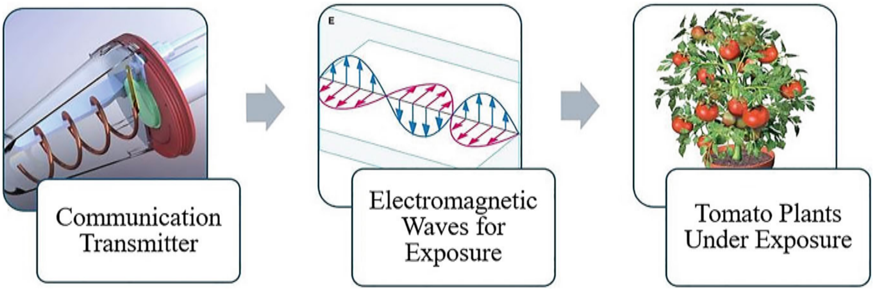


Fig. 1 Exposure illustration

The gene alteration has been reported in the case of photosynthesis in proteins. The chloroplast structure has been distorted. The biomolecular level effects have caused physiological changes in terms of plant growth [18]. The investigations have identified multiple deteriorative effects on the plant structure, growth, height, root length, leaf size, stem size, tissues, and molecular level changes in the plants [19–25]. It is strongly suggested that such findings should be made accessible to the general public for their long-term benefits.

2 Adopted Methodology

2.1 Radio Wave Exposure

The communication device was utilized radiating at 4G communication frequency spectrum. The frequency was set at 2300 MHz which is a common 4G communication frequency, and the communication mode was kept at continuous. Pulsed communication is another type of communication mode that can be given to plants for EM wave exposure. It was ensured that a continuous field strength was maintained at the tomato plants. The received field strength was more than 20 times higher than in normal circumstances that are available in open-air environments. This depicts the situation where crop production is quite near the mobile towers where the intended work is more applicable. Table 1 tabulates the technical parameters of the communication devices and targeted frequency. Figure 2 illustrates how directive the helix resonator is utilized for the intended tests. The omnidirectional antenna may reduce the field strength in the in- tended direction due to the property of having equidirectional radiation. The distance was kept in the near field for the measurements within laboratory conditions.

The parameters that affect the exposure effects on living tissues were frequency, distance, tissue thickness, or specific absorption rate, which varies with the type of plant tissue and species. The EM effects are categorized as thermal and non-thermal effects. A former investigation of 1.8 GHz frequency showed that out of two

Table 1 Transmitter technical parameters

Technical parameter	Specification
Modulation	Continuous
Polarization	LHCP
Antenna gain	~ 15 dBi
Radiation frequency	2.3 GHz

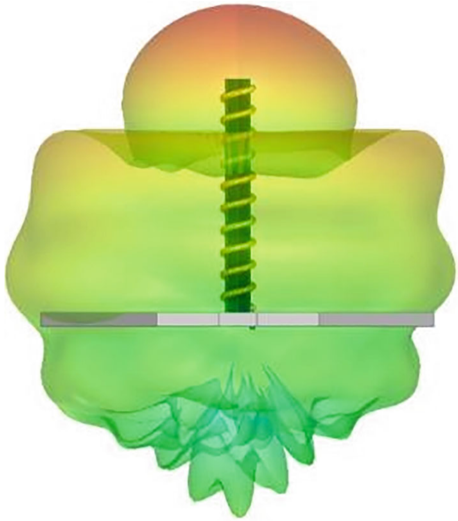


Fig. 2 Radiation pattern of helix transmitter

major categories non-thermal effects affect more negatively to plants because the EM field can modulate plant metabolism and even incorporate genetic mutations. Consequently, the presented investigation was governed to check 2.3 GHz frequency on tomato plant physiology and biochemical composition. The plant seed germination rate, physiology and growth parameters, viz., plant height, root length, dry and fresh weight, leaf and node count, leaf area, and leaf length were measured [4]. The selected biochemical composition was referred from standard methodology [26].

2.2 Specific Absorption Rate Analysis

The specific absorption rate (SAR) specifies the energy absorption rate of the tissue. It varies from plant to plant depending on the physiological parameters of plants. In the proposed case, the prime tested parameters were the leaves of tomato plants. The calculation of SAR can be given as [27]

$$\mathrm{SAR} = C \times \frac{dT}{dt}_{t \to 0} \quad (1)$$

The C specifies the heat capacity and T specifies the change in temperature over time (t). The SAR calculation of Eq. 1 provides the energy absorption rate without any dependency on the transmission frequencies. The equal field distribution within the tissue shall determine the withstanding capacity before the heat increases. The heat capacity of the tomato leaf is around 10,800 JK^{-1} kg^{-1}. It was derived that for more than 4 h of radiation on the leaf, the temperature raised to around 0.2° C. The SAR value of tomato leaves was found to be around 3.2×10^{-2} Wkg^{-1} [4].

3 Results and Discussions

The biochemical and physiological parameters of the tomato plant were analyzed. The results are depicted from Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12. Multiple true-to-type plants were picked. They were allowed to grow in a uniform environment. The selected plants were taken to the greenhouse region with higher signal strength. The strength was as high as 25 dB than the regular outer atmosphere. The exposure of 4G communication 2300 MHz signal was carried out for short, medium, and long ranges from as short as 12–120 h. Consistent physical conditions were maintained for all the growing plants for the duration of exposure. The temperature was maintained at around 25° C. The seed germination rate is shown in Fig. 3. The seeds were exposed for nearly a month duration under given circumstances. The physiological stressor is visible in Fig. 3 as the number of hours is increasing and reaching 120 h of exposure. Figure 4 exhibits plant growth parameters in terms of plant height and root length. It was observed that the root length fractionally increases at the initial exposure of up to 12 h, however, it significantly reduces as the exposure time increases. The plant height growth gets restricted with EM wave exposure. Plant weight also gets reduced as the exposure in- creases as shown in Fig. 5, this reflects the deterioration of plant biomass.

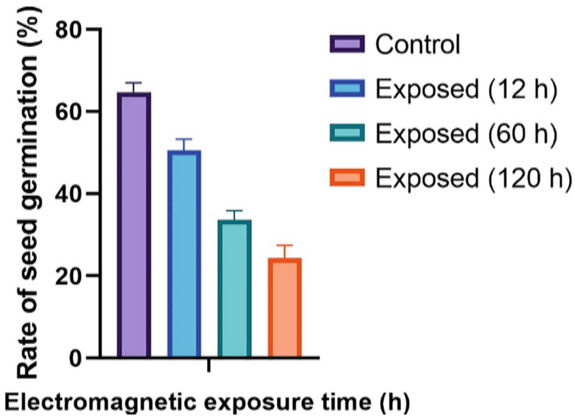


Fig. 3 Seed germination rate

Fig. 4 Plant growth parameters

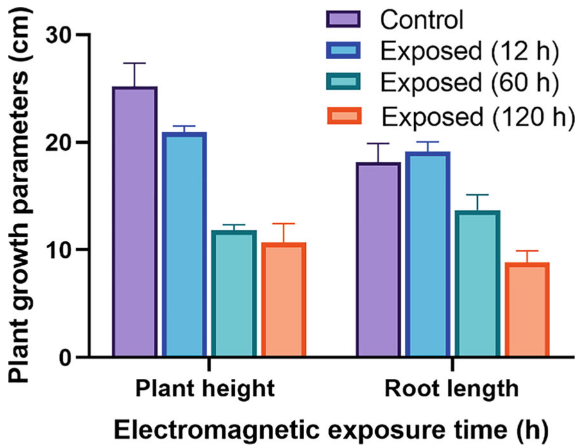


Fig. 5 Plant weight

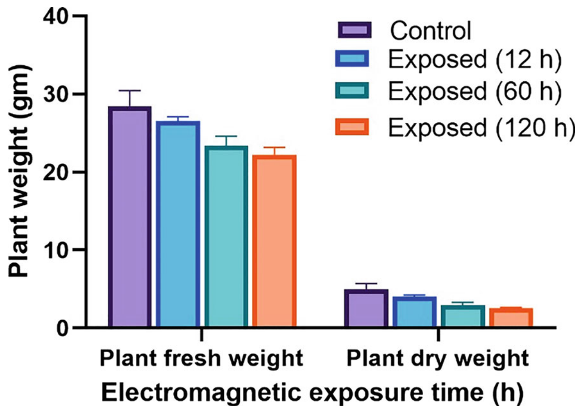
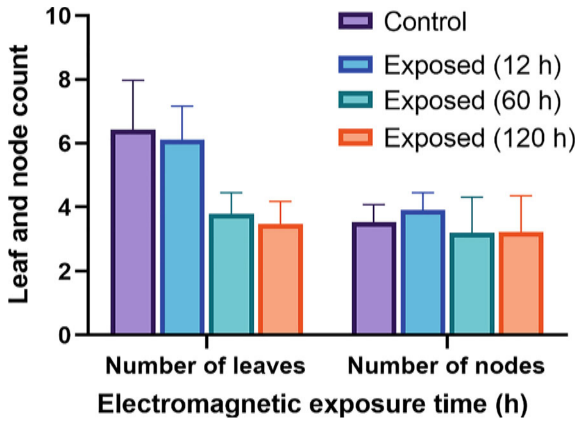


Fig. 6 Leaf and node count



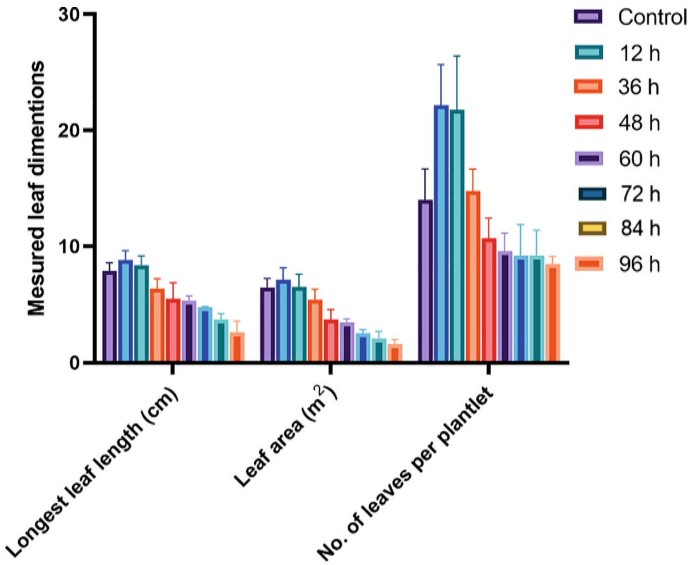
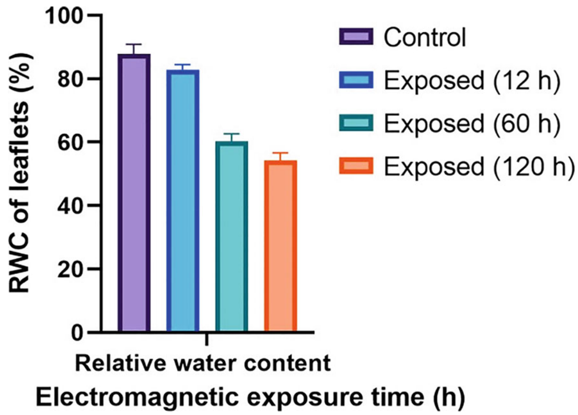


Fig. 7 Leaf physiological parameters

Fig. 8 Relative water content of tomato leaves



The tomato leaf count reduced slowly for initial exposure however, it was observed that the node count increased for similar EM wave exposure as illustrated in Fig. 6. As the exposure duration increased the leaf and node counts reduced. It could further reduce with higher exposure which is the gist of the proposed research targeting crop production on the farming land. Leaf area, leaf length, and number of leaves increased transiently up to 36 h of exposure showing activation of plant metabolism and defense system in response to abiotic stress in the form of EM exposure. Figure 7 depicts plant physiological parameters. The longest leaf length, leaf area, and number of leaves per plant increased during the shorter duration of continuous EM wave exposure.

Fig. 9 Chlorophyll content

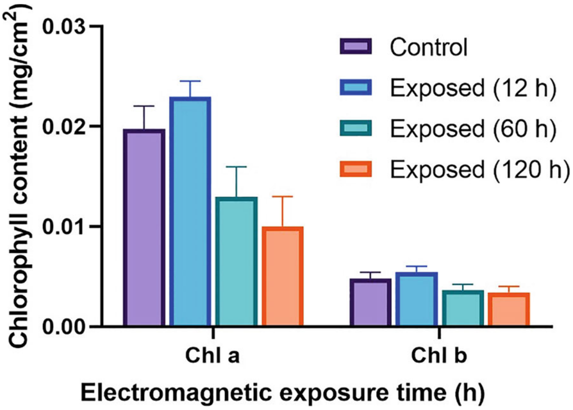


Fig. 10 Chlorophyll a/b content

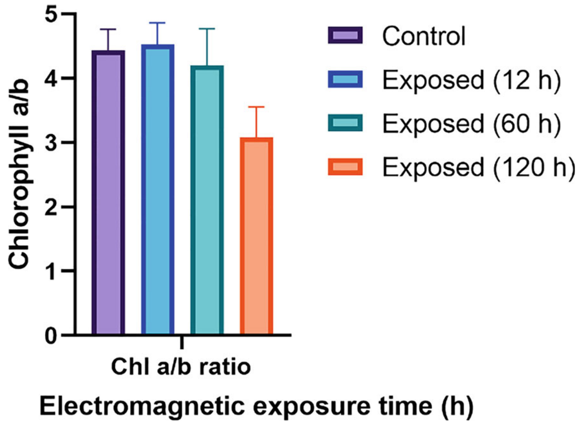
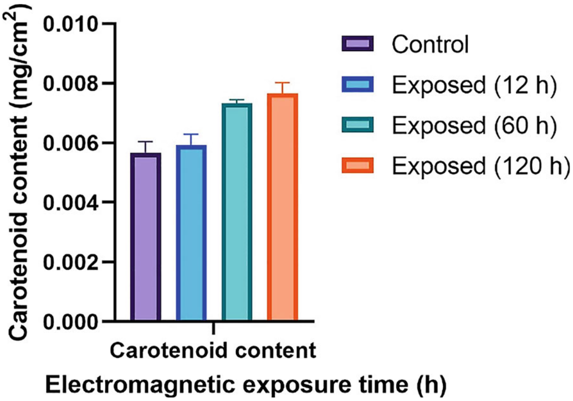


Fig. 11 Carotenoid content



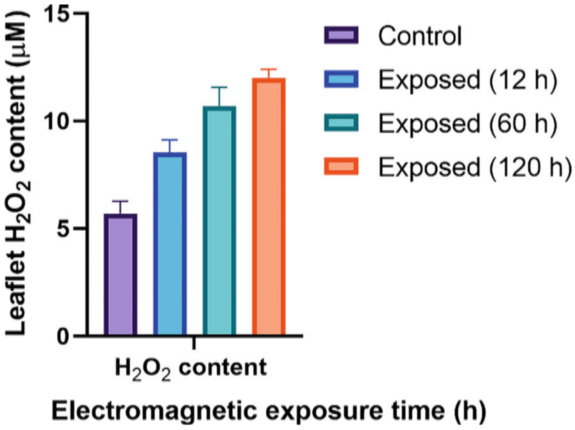


Fig. 12 Leaflet H2O2 content

As the exposure increases these parameters were substantially reduced showing the gloomy effects of the EM waves on plants. Relative Water Content (RWC) is extremely crucial for plant tissue homeostasis. The possible thermal effects of EM radiation continuously decreased RWC with the increase in exposure time as evident from Fig. 8.

Chlorophyll and Chlorophyll a/b contents as shown in Fig. 9 and 10 increased for a short duration of 12 h, which exemplified stress response in exposed plants. An exponential decrease thereafter showed harmful effects on the photosystem and biosynthesis of chlorophyll pigments, which is consistent with plant growth parameters. Chlorophyll contents are responsible for plant yield for many economically and medicinal important crop plants, thus affecting humankind in the greater sense.

Carotenoid pigments increased with exposure time which shows the induction of senescence or premature aging of plant tissue. Figure 11 exhibits the carotenoid content for the EM wave exposure which increases more than 20% as the exposure up to 120 h is given to the tomato plants. The exponential increase in the carotenoid content shows that a further increase in the exposure may cause a lot of harm to the plant with a higher number of exposure hours. H2O2 is a plant stress marker that is produced by peroxidase when reactive oxygen species content increases within the living tissue as shown in Fig. 12. EM exposure increased H2O2 content which signifies stress on exposed tissues. This exhibits that plants are under stress and the yield is going to be affected for the crops which has similar biochemical characteristics to that of the tomato plants.

4 Conclusion

The study analyzed the gloomy effects of electromagnetic waves on plants. It encompassed 4G communication frequency for the analysis. It was observed that tomato plants undergoing long-term exposure are significantly affected. The biochemical and physiological analysis revealed that such electromagnetic field exposure, either with a strong or weak strength, should be avoided for good crop production.

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