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Research Article

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Effects of 2.4 GHz electromagnetic radiation on morphological and physiological characteristics in *Cicer areitinum*

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ABSTRACT

Electromagnetic field radiation is an important effective stress factor on growth and development of plants. Plants are able to recognize and respond to their surrounding environment with high specificity. Our research focused on Cicer areitinum grown under 2.4 GHz electromagnetic field exposure and comparing them with the control. Two replicates were used in the experiment with 10 seeds in each sample. The seeds were spread on the moist filter paper in Petri dishes before they were placed in the experimental setup where they were exposed to electromagnetic radiation of 2.4 GHz. Control seeds were placed under similar conditions but without electromagnetic exposure. Morphological and physiological comparison of the treated and control samples showed that the percentage of seed germination has significant difference in average shoot and root length. A significant decrease in the leaf area, fresh and dry weight was observed. Physiological examination of experimental and control samples revealed significant decrease in the rate of chlorophyll a and chlorophyll b of electromagnetically exposed samples.

Key words: Electromagnetic field, chlorophyll, radiation, morphological, physiological

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INTRODUCTION

Electromagnetic radiation is a form of energy exhibiting wave-like behaviour as it travels through space. It has both electric and magnetic field components, which oscillate in phase perpendicular to each other and perpendicular to the direction of energy propagation. The entire electromagnetic spectrum is spread over a range of frequencies from extremely low frequency to high frequency ultraviolet rays, X-rays, gamma rays, and cosmic rays. Referring to the radiation exposures, EM radiation is classified as ionizing and non-ionizing radiation. Non-ionizing radiation has not enough energy to produce ionization in matter while ionizing radiation, characterized by frequencies higher that 3 x10^{15} Hz can (RK Singh, 2012; Lin, 2004; Macelloni *et al.*, 1998; T. Wong *et al.*, 2009). Plants are very sensitive towards different environmental stress. At the same time they can recognize and respond to this surrounding stress. The impacts of EMFs on plants is a question being explored since plants are just as readily exposed to low-level magnetic fields as humans as a consequence of power lines and other industrial technology. Belyavskaya (2004) found that weak electromagnetic fields suppressed the growth of plants, reduced cell division, intensified protein synthesis and disintegration in plant roots. The few recent studies on environmental effects of electromagnetic fields (EMF) have mostly focused on extremely low frequency (ELF) fields, such as those generated by overhead power cables (RK Singh, 2012). They mostly considered plants and not species that would be expected to be among them. Electromagnetic field of low frequency (10Hz) stimulated the growth of roots while for higher frequencies (240Hz) growth inhibits (Muraji *et al.*, 1998). Some workers have reported that electromagnetic field of low intensity caused a small but significant increase in the fresh weight of young plantlets of *Helianthus annuus* and

Triticum aestivum (Fischer *et al.* 2004). Seed germination of onion and rice speeds up if exposed to a weak electromagnetic field for 12 h (Alexander *et al.,* 1995). It has been observed that less attention was being paid highlighting the effect of EM radiation on plants since most of the area of research was based on exposure of EM radiation on human beings and animals. The present work focus on effects of electromagnetic radiations on seed germination and seedling growth of *Cicer areitinum*.

EXPERIMENTAL SECTION

2.1 Sample collection and experimental setup- Seeds of *Cicer arietinum* were obtained from Punjab Agricultural University, Punjab, as the quality and genetic purity was a big concern. Seeds were then surface sterilized with 0.1% Mercuric chloride ($HgCl_2$) solution to avoid fungal or bacterial contamination. They were then rinsed with distilled water thrice and blotted dry with filter paper. Then 10 seeds were placed with equal spacing on cotton in a sterilized petridish of 10 cm diameter. Cotton was kept moist by adding sufficient amount of distilled water. Two replicates of the petri dishes containing seeds were then placed for germination in a controlled laboratory in natural light at room temperature. One replicate was exposed to electromagnetic radiation of 2.4 GHz and is compared with that of control having the same setup but devoid of radiation.

2.2 Electromagnetic exposure set up- The set-up consists of a microwave source (analog signal generator) covering a frequency range from 250 kHz to 20 GHz (Fig. 1). A coaxial variable attenuator is used to feed the right amount of microwave power. A microwave amplifier of model no. 8349B Hewlett Packard Co., USA make has been used. A transition from coaxial to rectangular waveguide connection is required in order to feed the power to the antenna. It is obtained by a coaxial to waveguide transition. A 20dB cross coupler and E-plane bend is used to feed the power to a pyramidal horn antenna. A power sensor and a power meter are attached with cross coupler. The microwave amplifier output has been measured with power sensor and has been found to be 19.8dBm. Pyramidal horn antenna having dimensions of throat equal to 7.2 cm x 3.2 cm, mouth equal to 9 cm x 5 cm and mean axial length equal to 10 cm provides gain of 4.07 dB. Horizontal and vertical beam-widths of the pyramidal horn are 1.24 and 1.69 dB. Far-field criterion ($R \geq 2D^2/\lambda$) has been applied to calculate the distance between the pyramidal horn and the mid-plane of the seedlings and has been found to be 25 cm. Beamwidth of the horn antenna in electric and magnetic field planes has been taken into account to design the pot for the experimental set-up so that proper exposure can be provided to the seedlings. The seedlings have been kept in such a way that E-field is parallel to the seedlings. A low dielectric constant material (2.13) has been used to make the pot with dimensions of 19.2 cm x 17.6 cm x 20 cm. In order to minimize electromagnetic scattering the pot has been covered along all the four sides and the base by carbon-impregnated styrofoam microwave absorber. The upper portion has been kept open to provide proper environmental condition to the seedlings. The microwave absorbers have been tied together to avoid any change in the position of the pot with reference to the pyramidal horn antenna. In order to provide proper atmospheric conditions to the seedlings, pot temperature has been maintained at 24-27°C by circulating air. Seedlings were continuously exposed for 3 hours, i.e., from 10:00 to 13:00 hrs daily for 10 days.

Power transmitted from the pyramidal horn antenna has been found to be 64.78 mW. This was done by measuring the power input to the antenna with the help of power meter with power sensor attached to 20-dB cross coupler and subtracting the reflected power from the antenna that has also been measured by power meter.

Power density at a distance R is given by $P_D = P_t G_t / 4\pi R^2$ where P_t is the power transmitted into the pot, G_t is the gain of the pyramidal horn antenna. At the electromagnetic exposure frequency of 2.4 GHz, the power density has been found to be 0.03355 mW/cm^2.

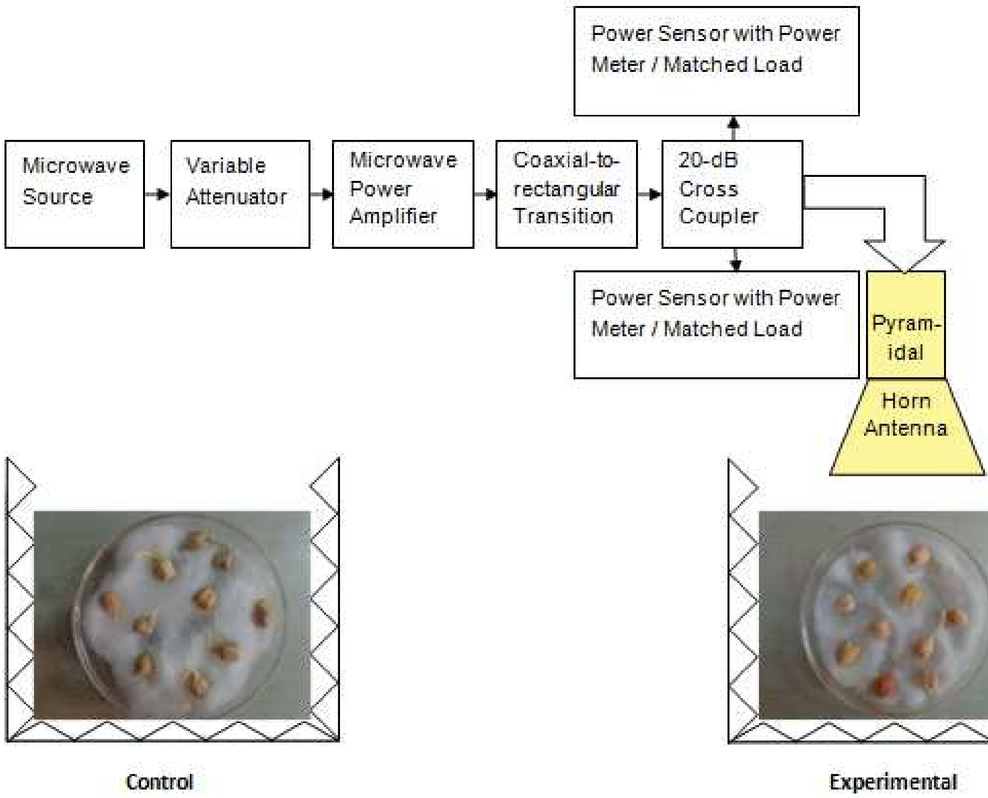

Fig. 1: Electromagnetic field exposure setup and position of control and experimental set of *Cicer areitinum*

2.4 Observation of seedling growth- The growth of seedling was monitored after two, four and six days. The root and shoot length were measured and fresh, turgid and dry weight was also determined. Fresh weight of seedlings was observed regularly at the interval of 2, 4 and 6 days. After recording the fresh weight seedlings they were soaked in water for 8 hours to get the turgid weight and then dried in oven for 4 hours to obtain the dry weight. With the help of the obtained data, relative water content (RWC) of the seedlings was calculated. The effect on overall seedling growth and weight due to electromagnetic exposure was compared with that of control.

RESULTS AND DISCUSSION

3.1 Effect of EMF exposure on root and shoot growth- Seedling growth of the seeds placed in the petridish exposed to EMF radiation have shown a remarkable variation with that of control. The root length of EMF exposed seed was observed 0.13cm, 0.28cm, 0.68cm at 2, 4 and 6 days, respectively. On the other hand, the root length of control seedlings was 0.23cm, 0.36cm, 1.03cm. In the same way, the shoot growth was also affected and the similar trend was observed showing 0.18cm, 0.23cm, 0.76 cm length after 2, 4 and 6 days in comparison to control having 0.31cm, 0.57cm, 1.36cm shoot length. This reveals that due to EMF exposure of 2.4 GHz, the physiological, biochemical and genetic disturbances in the seeds resulted in inhibited growth of root and shoot seedlings (Fig. 2)

3.2 Effect of EMF radiation on weight of seedlings- After 6 days the fresh weight of seedlings exposed to EMF radiation was 0.20g. On the other hand, the control seedlings were having the fresh weight of 0.24g. The turgid weight after 6 days was 0.31g of control and 0.25g of EMF exposed one. The dry weight of seedlings of both the control and EMF exposed also follow the same trend, i.e., 0.12g of control and 0.09g of the seeds exposed to EMF radiation. This reveals the fact that the net biomass and photosynthetic assimilates of the seedlings gets adversely affected by the application of electromagnetic radiation and as a result, the total dry matter gradually decreases with the increasing hours of EMF exposure (Fig. 3).

3.3 Effect on chlorophyll content on seedlings- The seedlings growing in EMF radiated environment was examined periodically at 10, 15 and 20 days to determine the chlorophyll content with the help of spectrophotometer. It was found that there is an increasing trend in Chl a and Chl b as increasing number of days but if compared to control, the chlorophyll content is comparatively less in the seedlings exposed to EM radiations. This shows that due to electromagnetic radiations seedlings show inhibited growth and development that result in decreasing trend of chlorophyll content in young leaves (Fig. 4).

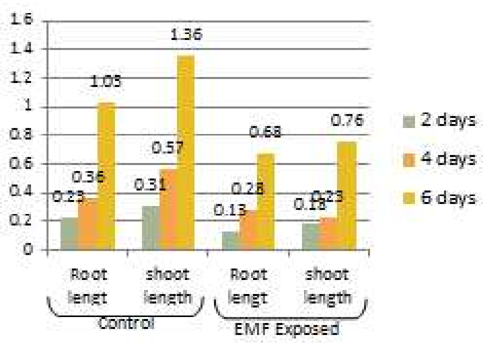

Fig. 2: Root & shoot length of seedlings under control and EMF exposed conditions

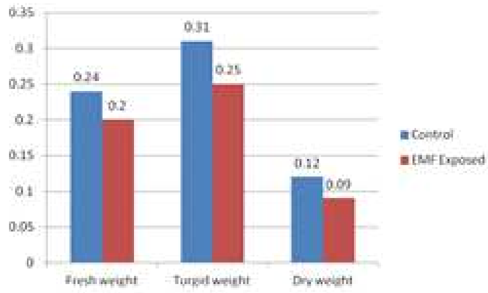

Fig. 3: Fresh, dry and turgid weight of seedlings under control and EMF exposed conditions

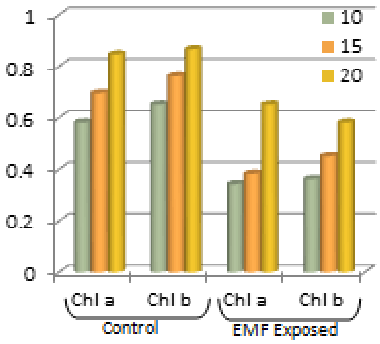

Fig. 4: Chlorophyll a & b content of seedlings under control and EMF exposed conditions

CONCLUSION

The present study concludes that the exposure of electromagnetic radiation of 2.4 GHz to the seeds of *Cicer arietinum* adversely affects the growth and development of seedlings. The overall biomass of the seedlings was significantly decreased due to EM radiations. As there are many sources that are contributing to electromagnetic radiations and the emission is causing a great damage to many edible parts of plants, all the results of the present study draw attention towards the hazardous effects of EM radiation.

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