# Are radiofrequency radiations crop friendly?

By

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(2018-11-149)

MSc. Seed Science and Technology

Seminar report

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# DECLARATION

I, **Harshaprada, K. (2018-11-149)** hereby declare that the seminar report titled **'Are radiofrequency radiations crop friendly?'** has been completed by me independently after going through the references cited here and I haven't copied from any of the fellow students or previous seminar reports.

Vellanikkara Harshaprada, K.

Date: 27/01/2020 (2018-11-149)

# CERTIFICATE

This is to certify that seminar report titled **‘Are radiofrequency radiations crop friendly?’** for the course SST. 591 has been solely prepared by **Harshaprada, K. (2018-11-149)** under my guidance, and she has not copied from seminar reports of seniors, juniors or fellow students.

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# CERTIFICATE

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# Are radiofrequency radiations crop friendly?

## 1. Introduction

In the recent past Information technology (IT) has broken through geographical barriers and distance, integrating the entire world into a cohesive global village. The extremely rapid advancements in IT that has revolutionised communication is not without its fallout. The use of wireless devices is rampant in all walks of life. Most of the telecommunications devices as well as non-communication devices such as microwave ovens and radars emit Radiofrequency-Electromagnetic Radiation (RF-EMR) energy. These radiations have been found to possess a profound influence on the metabolism, growth and behaviour of humans and many animals.

### 1.1 Radiofrequency Radiations

Radiofrequency-Electromagnetic Radiation (RF-EMR) or Radiofrequency Radiation (RFR) consists of waves of electric and magnetic energy moving together through space at the speed of light. It is the transfer of energy by radio waves. RF-EMR lies in the frequency range between 3 kilohertz (kHz) to 300 gigahertz (GHz) of the electromagnetic spectrum. These are non-ionizing radiation, meaning that it has insufficient energy to break chemical bonds or remove electrons (ARPANSA, 2002).

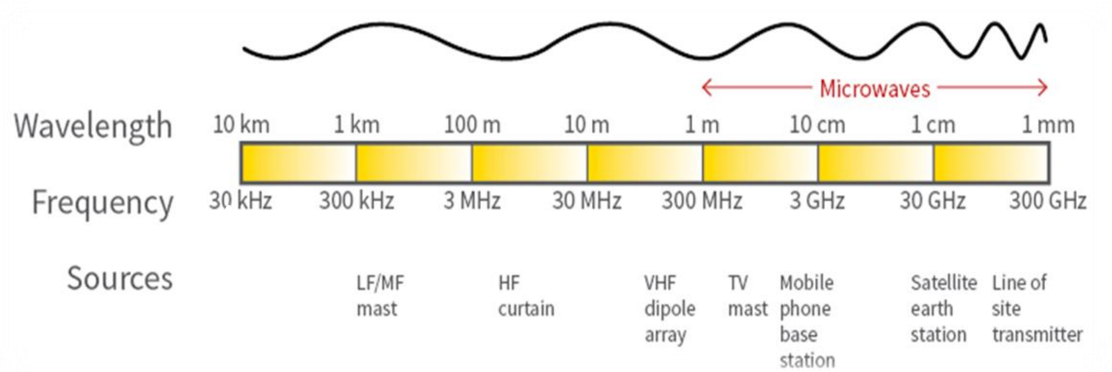



**Plate 1. Radiofrequency radiation spectrum**

## 2. Sources of radiofrequency radiations

RF-EMR is produced by both natural and artificial sources. Natural sources like the sun, the earth and the ionosphere, emit low level RF fields. Artificial sources of RF-EMR are mainly those used for telecommunications purposes. Radio and television broadcasting, mobile phones, wireless networks such as Wi-Fi, cordless phones, police and fire department radios, point-to-point links and satellite communications emit RF-EMR. Other sources include microwave ovens, radar, industrial heaters and sealers, and various medical applications.

Most RF fields found in the environment are due to commercial radio and TV broadcasting, and from telecommunications facilities (such as wireless connected devices). RF exposure from radio or TV broadcasting is generally less compared to wireless devices. The wireless devices work under high frequency range and hence releases more energy.

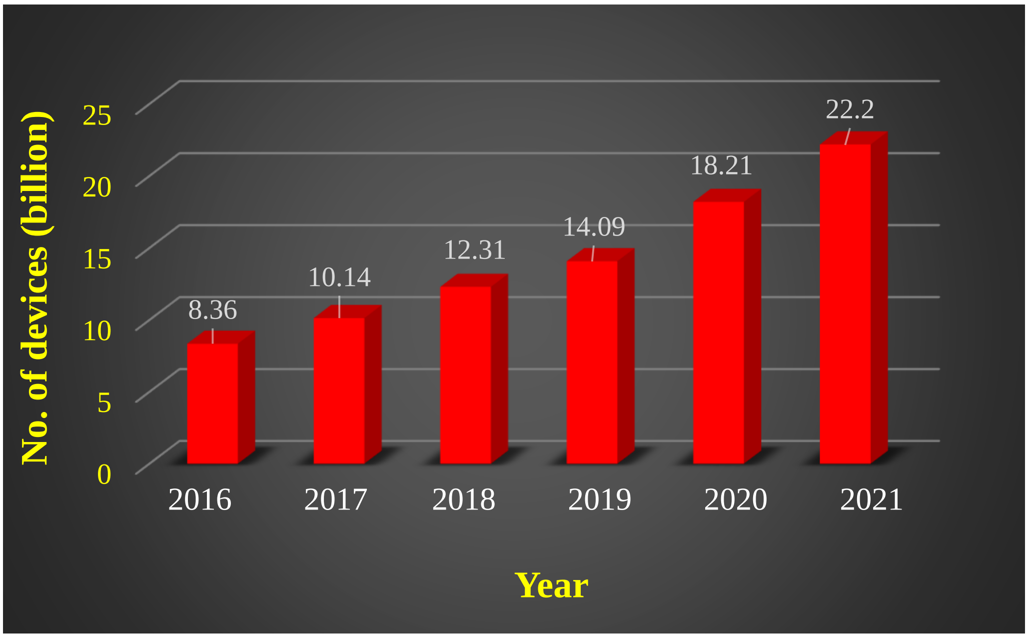
## 3. Why are RF radiations a concern?

In May 2011, the International Agency for Research on Cancer (IARC) classified RF-EMR as a possible human carcinogen (Group 2B) (Hardell, 2017). In spite of such adverse findings, the usage of RF-EMR emitting devices are on the rise.

### 3.1 Usage of wireless devices: World scenario

According to Market Research Report (2019), the market size of radiofrequency components globally grew by 14 per cent in 2019 from 18.06 billion USD in 2018. STATISTA (2019) reported that, there is a vast increase in the usage of wireless connected devices over the years and is expected to reach 22.2 billion devices by the year 2021.

**Fig 1. Increase in the usage of wireless connected devices: World scenario**



### 3.2 Usage of wireless devices in India

The wireless data usage for communication and entertainment in India also witnessed unprecedented growth (TRAI, 2019).

**Table 1. Usage of wireless devices in India**

| Year | No. of Wireless Subscribers (million) | Growth in wireless subscribers (%) |
|---|---|---|
| 2014 | 943.97 | - |
| 2015 | 1,010.89 | 7.09 |
| 2016 | 1,127.37 | 11.52 |
| 2017 | 1,167.44 | 3.55 |
| 2018 | 1,176.00 | 0.73 |

Such widespread usage in wireless devices all over the world, is not without repercussions on the well-being of humans and animals.

### 3.3 Health effects of radiofrequency radiations

Several organizations like Occupational Safety and Health Administration (OSHA), Federal Communications Commission (FCC), World Health Organization - International Agency for Research on Cancer (WHO/IARC) and Centers for Disease Control and Prevention (CDC), individually or collectively, have identified potential thermal and non-thermal effects of RF radiations such as

1. Blindness, sterility, heating of tissues (eyes and testes are particularly vulnerable), burns, electrical shocks (Thermal effects).
2. Alteration of body's circadian rhythms, immune system, and nature of the electrical and chemical signals communicated through the cell membrane (Non-thermal effects)
3. Possible carcinogenic activity in humans (Group 2B)

## 4. Specific absorption rate

Specific Absorption Rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field. It is also defined as the power absorbed per mass of tissue and its unit of measurement is watts per kilogram (W/kg)

SAR is usually averaged either over the whole body, or over a small sample volume (typically 1 g or 10 g of tissue). The FCC (2012) has specified that the phones are not exceed a SAR level of 1.6 watts per kilogram (W/kg).

## 5. Plants are the ideal study materials

The vast majority of the RF-EMR studies have focused on animals and humans because of health concerns, with contradictory or non-conclusive results. Roux *et al*.,(2006) reported that, plants could serve as outstanding models compared to animals for the conduct of such investigations because they are immobile and so can maintain a constant orientation in the RF field, their specific scheme of development *i.e.*, high surface area to volume ratio makes them ideally suited to efficiently intercept radiations. It is also quite easy in plants to achieve genetically stable plant lines through the selection of species that favor asexual reproduction or self-pollination. Indeed, plants actually perceive RFR of even small amplitudes and transduce them into molecular responses and/or alterations of their developmental scheme. Furthermore, metabolic mutants are easily available for several species and constitute invaluable tools to understand the way these signal are transduced (Beaubois *et al*., 2007).

## 6. Exposure of plants to RF radiations

Due to the wide variety of electromagnetic waves, physicians developed several electromagnetic exposure facilities which are mainly used for radiofrequency compatibility testing.

### 6.1 Components of experimental set-up for exposure of plants to RF radiations

Generally, the exposure set-up is made up with three basic elements such as:

(i) RF source (radiofrequency generator, Gunn oscillator)

(ii) Radiating element (antenna, a strip-line)

(iii) A structure that allows the propagation of radiofrequency waves and the exposure of the sample (test area)

The simplest exposure setup relies on the use of standard cell phones as a source of RF-EMF, radiating in an open-area test site. This apparatus has the advantage of being simple and economical, it poses many limitations that may compromise the quality of the exposure and also exposes the biological samples to the uncontrolled electromagnetic ambient environment (Sharma *et al*., 2009)


**Plate 2. RF generator**

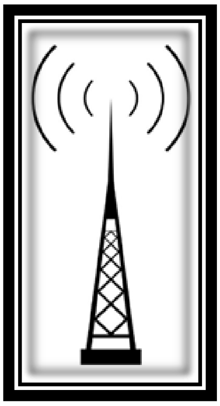


**Plate 3. Antenna**


**Plate 4. Test area**

The use of shielded rooms is a good solution to overcome this issue. Indeed, anechoic chambers provide shielded enclosures, which are designed to completely absorb reflected electromagnetic waves. However, these facilities are often large structures requiring specific equipment and costly absorbers to generate an incident plane wave (far-field illumination) and are consequently seldom used for plant exposure (Senavirathna and Asaeda, 2014).

### 6.2 RF exposure signals

The RF generator can produce two very different types of wave modes, which are used to expose the plants. The most commonly encountered mode is the continuous wave (CW) mode, in which the biological samples are continuously exposed for a specific duration to RF waves of given frequency and amplitude (few $Vm^{-1}$).

The pulsed electromagnetic field (PEMF) mode is seldom used because of the scarcity and great complexity and the difficulty to design the dedicated antennae, which able to deliver such ultra-short power waves.

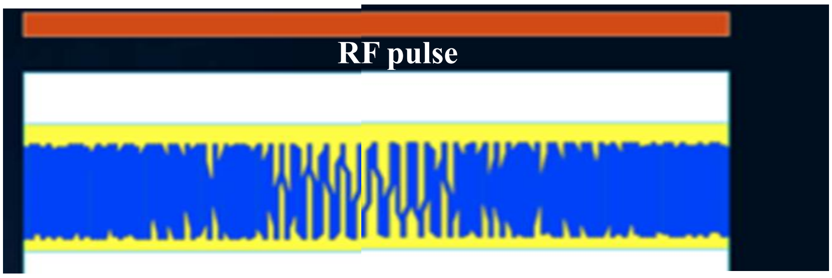



**Plate 5. Continuous wave (CW) mode**

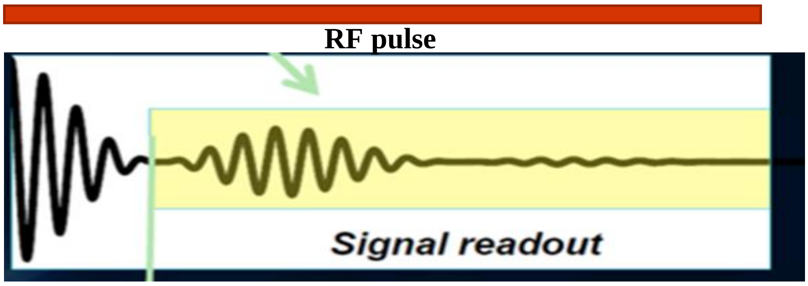



**Plate 6. Pulsed electromagnetic field mode**

The RF-EMF could also be modulated (usually much lower frequency). Only a few studies explicitly addressed modulation effect on biological responses. Racuciu *et al*., (2008) exposed maize caryopses to low levels (900MHz RF field, for 24h) in either continuous wave (CW), amplitude modulated (AM), or frequency modulated (FM) modes. They found that 12 days old plant lengths were reduced by about 25% in modulated fields (AM or FM type) compared to control (unexposed samples). While, CW exposure had an opposite (growth stimulation) effect, suggesting that EMF modulation of waves actually modifies biological responses.

## 6.3 Devices for exposure of plants to RF radiations

Considering the limitations of open area testing, many small volume devices have been developed to aid in more precise testing. A few of them are enumerated below.

### 6.3.1 Transverse Electromagnetic (TEM) Cell

TEM cells are usually quite small (about 50cm long × 20cm wide) and therefore only allow the use of seeds or seedlings as plant models. They consist of a section of rectangular coaxial transmission line tapered at each end to adapt to standard coaxial connectors. A uniform plane wave of fixed polarization in fixed direction is generated in the sample space for experiments between the inner conductor (septum) and the upper metallic wall. Because this device is enclosed, high amplitude radiations can be developed with relatively little injected power.

The main TEM cell limitation is that the upper useful frequency is bound by its physical dimensions limiting the practical size of samples at high frequency.

### 6.3.2 The Gigahertz Transverse Electromagnetic (GTEM) Cell

It is emerged as a more recent EMF emission test facility. It is a hybrid between an anechoic chamber and a TEM cell and could therefore be considered as a high frequency version of the TEM cell. The GTEM cell comprises only a tapered section, with one port and a broadband termination. This termination consists of a 50Ω resistor board for low frequencies and pyramidal absorbers for high frequencies.

This exposure device removes the inherent upper frequency limit of TEM cell, antenna set-up is not required and high field strength could be achieved with low injected power.

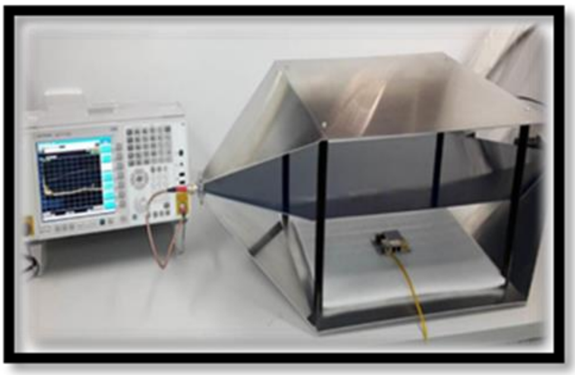


**Plate 7. TEM Cell**

**Plate 8. GTEM Cell**

### 6.3.3 Mode Stirred Reverberation Chamber (MSRC)

The specialized culture chamber that stands in the "working volume" where the electromagnetic field characteristics have been extensively characterized and is developed by H.A. Mendes in 1968.

It consists of a double-sided metallic walls, the emitting antenna, the rotating stirrer, and the specialized culture chamber. While this equipment is expensive and technically difficult to set up, it is the art in terms of electromagnetic field characteristics, allowing the establishment of an isotropic and homogeneous field in a volume large enough to hold a dedicated plant culture chamber (either transparent or shielded toward EMF) and so, it permits testing on large plants, in an adequate controlled environment.

**Plate 9. Mode Stirred Reverberation Chamber**

## 7. Response of plant system to RF radiations

Vian *et al*., (2016) stated that the biological responses of plants depends on their ability to perceive and interact with radiations. These responses can take place at subcellular level, implying to modification of enzymatic activities (biochemical response) or alteration in gene expression (molecular response) or result in growth modifications at the whole plant level (morphogenetic response).

### 7.1 Biochemical response

Biochemical response in plants mainly occurs due to alteration of enzymatic activities. ROS (reactive oxygen species) metabolism is very often activated after plant exposure to radiations. As a result, enzymatic activities such as peroxidase, catalase, superoxide dismutase and ascorbate peroxidase *etc*., may get altered and may lead to $H_2O_2$ production, MDA increase and protein damage (Tkalec *et al*., 2007).

#### 7.1.1 Effect of mobile phone radiations on morphological and biochemical parameters of mung bean (*Vigna radiata*) and wheat (*Triticum aestivum*) seedlings (Afzal and Mansoor, 2012)

The study aimed to observe the morphological and biochemical changes induced by cell phone radiations on Mung bean (*Vigna radiat*a) and Wheat (*Triticum aesti*vum) seedlings. The seeds of mung bean and wheat that were obtained from National Agricultural Research Centre (NARC), Islamabad, were imbibed in distilled water for 8 h, placed in 8×4 inch air tight plastic boxes, lined with filter paper moistened with distilled water. A commercially available GSM mobile phone (900 MHz band with modulated voice and low frequency signal) was placed in box with 25-30 seeds around it and during the exposure cell phone was placed on talking mode in vibration and phone battery was kept charged and one sample is kept as control.

After 72 h, germination (%), seedling length and fresh weight (F.W) were recorded. Seedlings of equal fresh weight were allowed to dry at 70ºC for 24 h to record the dry weight (D.W). Lipid peroxidation is estimated by measuring the amount of malondialdehyde (MDA) content, which is a product of lipid peroxidation. Effects of mobile phone radiations on the activity of antioxidant enzymes like Ascorbate Peroxidase (APX), Guaiacol Peroxidase (GPX) and Catalase (CAT) were studied.

**Results:**

1. **Effect of cell phone radiations on morphological parameter of seedlings**: The study indicated that the effect of cell phone radiations on germination parameters was highly significant and varied between the crops studied. Results showed that germination in both unstressed as well as stressed mung bean was found to be 100 per cent. However, thew wheat genotype recorded 77.3 mean germination per cent for unstressed seedlings which reduced to 74.69 per cent in stressed seedlings.

   Seedlings length in both crops were found to be reduced under stressed condition with more reduction in wheat seedlings as compared to mung bean. Similarly F.W and D.W were reduced in treated plants in comparison with control (Table 2).
2. **Effect of cell phone radiations on biochemical parameter of seedlings:** The MDA content was high in stressed samples as compared to unstressed ones of both genotypes. The GPX, APX and CAT activity were increased when mobile phone radiation was given to mung and wheat seedlings as compared to unstressed seedlings. The contents of protein was reduced with enhanced MDA and various enzymes activities after exposure in both the crops (Table 3).

**Table 2. Morphological parameters of mung bean and wheat seedlings**

| Parameters | Mung bean | | Wheat | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| Germination (%) | 100.00 | 100.00 | 77.30 | 74.69 |
| Seedling length (cm) | 13.08 | 10.30 | 12.46 | 6.24 |
| Fresh weight (g) | 0.25 | 0.23 | 0.24 | 0.22 |
| Dry weight (g) | 0.03 | 0.021 | 0.08 | 0.08 |

**Table 3. Biochemical parameters of mung bean and wheat seedlings**

| Parameters | Mung bean | | Wheat | |
|---|---|---|---|---|
| | Control | Treatment | Control | Treatment |
| **Protein** | **283.30** | **236.60** | **340.00** | **250.00** |
| MDA | 30.78 | 59.77 | 33.86 | 61.45 |
| GPX | 0.55 | 0.75 | 34.35 | 63.2 |
| APX | 1.92 | 4.21 | 4.13 | 4.70 |
| CAT | 0.02 | 0.10 | 0.03 | 0.09 |

### 7.1.2 Electromagnetic waves from GSM mobile phone simulator increase germination and abiotic stress in *Zea mays* L. (Zareh and Mohsenzadeh, 2015)

Before exposure to RFR, the seeds of maize were soaked for 24 h on moist, sterile filter paper inside petri dishes (90 mm diameter). The seeds were exposed to a radio frequency (EMF) of 900 MHz for 48h. Three groups of seeds were used in this study. The seeds in the first group were only exposed to RF radiation emitted from a mobile phone simulator. The second group was only exposed to the simulator when it was switched off, and the third group served as the control. The exposure duration for all groups was 48 hours against the simulator system.

Thirteen-day-old maize plants were studied for 3 days-as exposed to EMF for 3 hours during the day and 5 hours during the night and including control for estimation of proline. 100 milligrams of frozen plant material and was homogenized in 1.5 ml of 3% sulphosalicylic acid and the residue was removed by centrifugation. Its absorbance was determined by a spectrophotometer at 520 nm via standard curves.

**Results:**

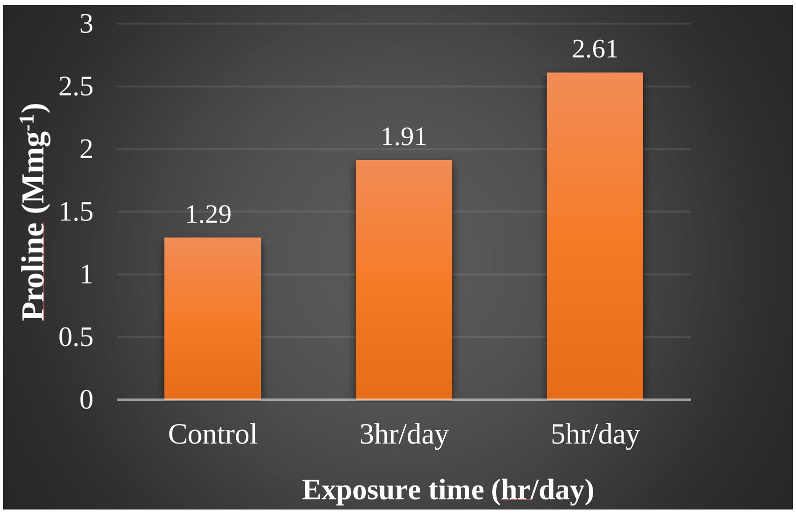
1. **Effect of GSM on seed germination**: The rate of germination among the treated seeds were higher than the untreated seeds. In this experiment, seed germination was found to increase significantly (98.8%) when exposed to 940 MHz, sourced from the simulator system (Table 4).
2. **Effect of GSM on proline content:** Proline content increased in both treatment groups, but the greater increase was attributed to 5 hours of exposure (Fig. 2).

**Conclusion:** The increase in proline content can counter measure against abiotic stress.

**Table 4: Effect of RF radiations at 940 MHz on germination in *Zea mays***

| Treatment | Germination % | GSM simulator |
|---|---|---|
| Control | 2±/ 03 | Out of system |
| Treatment 1 | 98/8 ±/04 | Inside system |
| Treatment 2 | 3±0/04 | Switch off |

**Fig. 2: The effect of RF radiations at 940 MHz on proline content in *Zea mays***



## 7.2 Molecular response

While numerous reports focused on alteration of enzymatic activities after exposure to RFR, only a few studies concentrate on gene expression modifications. So far, studies to elucidate the alterations in gene expression have been reported in *Lycopersicon esculentum* and *Arabidopsis thaliana*.

### 7.2.1 Alteration of genes in Tomato:

**Effects of long term exposure to RF/MW radiations on the expression of stress proteins in *Solanum lycopersicon* (Rammal *et al*., 2015)**

The study aimed to determine whether the exposure to (EMF) of frequency 1250 MHz can modify the expression of stress proteins in tomato plant and influence their biological function and considered two stress proteins *i.e*., the proteinase inhibitor (*PinII*) and the *Lycospersicon esculentum* basic leucine Zipper1 (*lebZIP1*). The proteinase inhibitor protect plants against insects and herbivores by reducing the digestibility and nutritional value of leaf protein and basic leucine Zipper1 help plants in self-defense.

Seeds of *L. esculentum* have been sown in 6 pots, and then chambered for 3 weeks (until the fourth terminal leaf appears). Three of them were exposed to the radiofrequency radiation (1250 MHz) and the other 3 pots were placed in another room without exposure to radiation. Bradford method was used to monitor the concentration of total protein and to show the change of total protein concentration of the exposed cells compared to non-exposed control cells. mRNA extraction was done by using Tri-reagent and was isolated from frozen tissues. cDNA synthesis was done by using RT-for-PCR kit (BD Biosciences) and then real-time quantitative PCR (RT-qPCR) analysis was carried.

**Results:**

1. Germination and growth of seeds: After 10 days of exposure, the stems were long and contain less leaves than the control plant (Plate 10). However, after 20 days of exposure, the stems were long and contain more leaves than the non-exposed ones. The leaves were larger and thicker in comparison with those of the control plant (Plate 11).
2. Protein accumulation: Bradford's dosage and quantification of the bands after SDS PAGE evidence the increase of 1.87 in total protein level

3. RT-PCR: The effects of electromagnetic exposure on the rate of the synthesis of mRNA of *Pin II* and *lebZIP1* were studied and the result shows a higher expression of mRNA in exposed plants (Plate 12)
4. Real time quantitative-PCR: The results showed that RF/MW exposure induced 3.2 fold accumulation of mRNA of *LebZIP1* (Fig. 3) related to stress and 2 times the accumulation of the mRNA of *PinII* (Fig. 4)


**Plate 10. Tomato seedlings after 10 days exposure**

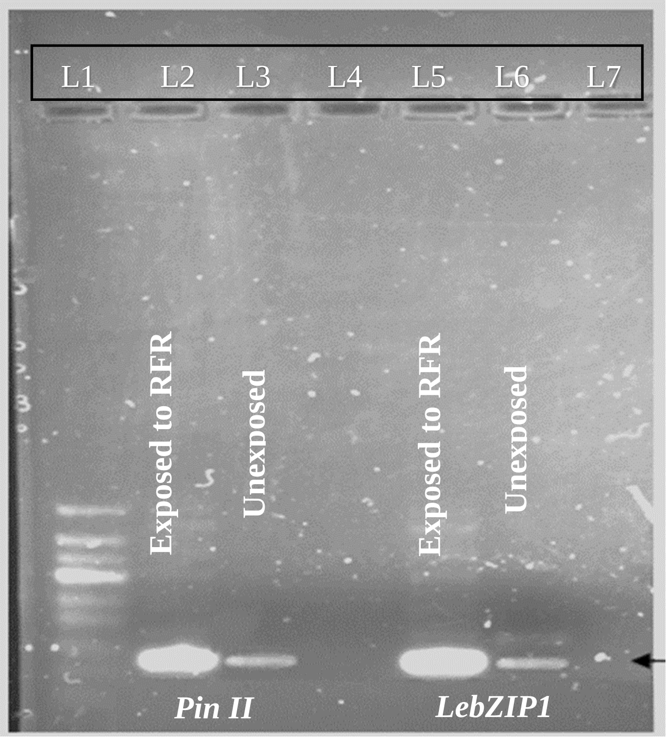

**Plate 11. Tomato seedlings after 20 days exposure**

**A: Exposed**

**B: Unexposed**

**Table 5: Alteration of gene expression in tomato on exposure to RF radiation**

| Sl. No. | Gene | Function | Response | Reference |
|---|---|---|---|---|
| 1 | *cmbp* | mRNA metabolism | Up-regulated | Roux *et al*., 2006 |
| 2 | *lebZIPI* | Transcription factor | Up-regulated | Vian *et al*., 2006 |
| 3 | *pin2* | Proteinase inhibitor | Up-regulated | Beaubois *et al*., 2007 |
| 4 | *cam* | $Ca^{2+}$ signal transduction | Up-regulated | Roux *et al*., 2008 |
| 5 | *cdpk* | $Ca^{2+}$ signal transduction | Up-regulated | Roux *et al*., 2008 |




1- DNA Ladder
4, 7 - Negative control

**Plate 12. Semi-quantitative analysis of RNA expression by RT-PCR in tomato on exposure to RF radiation.**

**Fig. 3 Accumulation of mRNA of *LebZIP1* transcript in tomato on exposure to RF radiation**

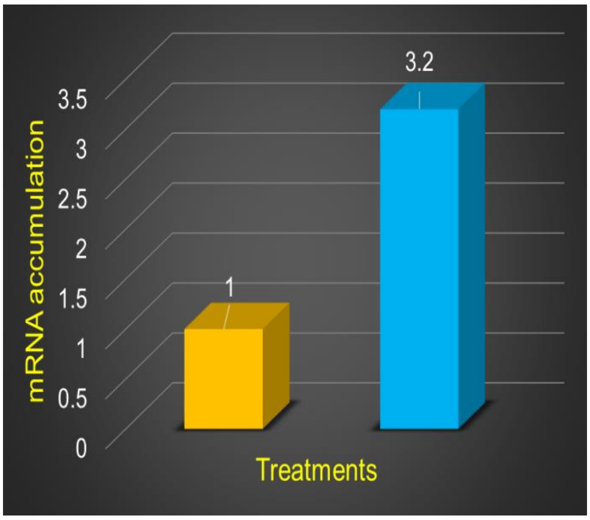
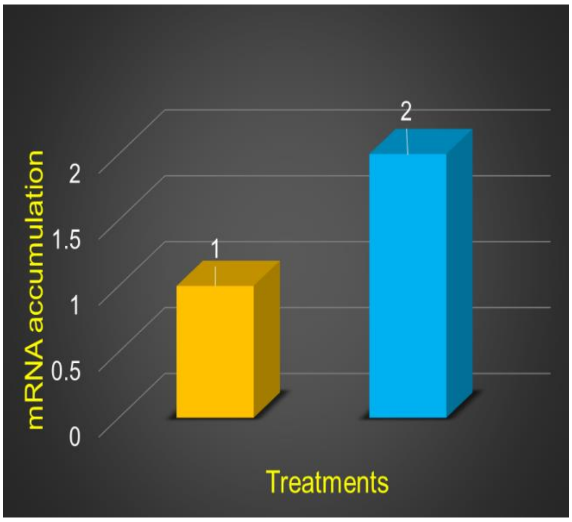



**Fig. 4 Accumulation of mRNA of *PinII* transcript in tomato on exposure to RF radiation**



### 7.3 Morphogenetic response

The biochemical and molecular modifications observed after exposure to RFR and described in the previous paragraphs might induce morphogenetic alterations of plant development. Exposure treatments are effective at different stages of plant development (seeds, seedlings, or whole plants) and may affect different organs or developmental processes including seeds germination and stem and root growth, indicating that biological samples of even small sizes (a few mm) are able to perceive RF-EMF (Vian *et al*., 2016).

#### 7.3.1 Effect of mobile phone radiation on nodule formation in the leguminous plants (Sharma and Parihar, 2014)

The study was conducted with the aim to check the effect of 2G and 3G mobile phone radiations on Pea and Fenugreek.

Seeds of Pea and Fenugreek were soaked in DW for 8 hours. The seeds were then placed in air tight plastic boxes lined with filter paper moistened with distilled water. A Nokia 2690 mobile phone (2G) with frequency band 850- 1850 MHz was used to irradiate the seeds and same sample of seeds were taken as control without exposing towards radiations to compare the effect of radiations on Pea and Fenugreek. Different exposure time subjected to the seeds to check the effect of radiations like ½ hour, 1 hour, 2 hours, 4 hours and 8 hours. After this the seeds were left for germination at least for 72 hours and then further tests are conducted to evaluate the effect of radiation on seedling and compare with the control.

For finding the effect of variations in frequency, the other set of seeds was irradiated by the mobile phone Samsung GT B7722 with frequency band 900- 1900MHz, having 3G technologies. For performing the experiment one set of seeds were exposed to radiations and other was taken as control in which no radiations were given as in 2G.

After 72 hour of radiations exposure, morphological analysis was done by note down the number of seeds germinated, seedling length estimation through length of plumule and radical. Seedlings allowed to drying at 70ºC for 24 h to record the dry weight.

After radiation exposure one set of control and irradiated seeds were sown in the pots and left them for minimum 45 days as this period is sufficient for nodule formation in the plant. The pots were watered daily for proper growth and development.

Pea Seeds with 2G exposure | Pea Seeds with 3G exposure | Fenugreek Seeds with 2G exposure | Fenugreek Seeds with 3G exposure

**Plate 13. Pea and Fenugreek Seeds with radiation exposure**

**Results:**

1. The germination per cent of control is less than 8 hour radiated seedlings. The exposure for short time does not show more effect on the seedling. As the exposure time increased, the germination per cent also get increased. The seed length and dry weight also show an increase with increase in exposure time period in case of both the treatments (Table 7 & 8) and fenugreek also followed the same trend (Table 9 & 10).
2. After the 45 days the different changes has been observed in the plant root of pea exposed with 2G and 3G mobile phone (Fig.5). The root length increased in irradiated seedling as compare to control and also the number of nodules and diameter of nodule increased. Same results were obtained in case fenugreek nodulation (Fig.6).

**Table 6. Germination and seedling growth in pea on exposure to RF radiations from mobile phones**

| Time of exposure | Germination (%) | | Seedling length (cm) | |
|---|---|---|---|---|
| | 2G phone | 3G phone | 2G phone | 3G phone |
| Control | 86.66±5.77 | 83.33±5.77 NS | 2.64±0.30 | 16.33±2.08 |
| ½ hour | 73.33±11.54 | 86.66±11.54 NS | 2.77±0.32 | 19.33±1.54 |
| 1 hour | 93.33±5.77 NS | 93.33±5.77 | 2.95±0.38 | 21.66±2.30 |
| 2 hour | 93.33±5.77 NS | 83.33±5.77 NS | 2.93±0.32 | 19.76±5.40 |
| 4 hour | 90.00±10 | 86.66±11.54 NS | 3.03±0.27 | 22.93±4.40 |
| 8 hour | 93.33±5.77 NS | 83.33±15.27 | 3.07±0.30 | 22.30±5.62 |

**Table 7. Dry weight of pea seedling on exposure to RF radiations from mobile phones**

| Time of exposure | Dry weight of seedling (g) | |
|---|---|---|
| | 2G phone | 3G phone |
| Control | 1.80±0.05 | 1.77±0.66 |
| ½ hour | 1.86±0.02 | 1.81±0.03 |
| 1 hour | 2.06±0.04 | 1.80±0.04 |
| 2 hour | 2.12±0.08 | 1.97±0.04 |
| 4 hour | 2.48±0.45 | 2.00±0.11 |
| 8 hour | 2.51±0.29 | 2.05±0.05 |

**Table 8. Germination and seedling growth in fenugreek on exposure to RF radiations from mobile phones**

| Time of exposure | Germination (%) | | Seedling length (cm) | |
|---|---|---|---|---|
| | 2G phone | 3G phone | 2G phone | 3G phone |
| Control | 93.33±5.77 NS | 100.00NS | 2.83±0.05 | 3.60 ±0.52 |
| ½ hour | 96.66±5.77 | 96.66±5.77NS | 2.76±0.32 | 2.93±0.94 |
| 1 hour | 100.00NS | 96.66±5.77NS | 2.93±0.28 | 3.86±0.57 |
| 2 hour | 93.33±5.77 NS | 100.00ns | 3.10±0.20 | 3.63±0.37 |
| 4 hour | 100.00NS | 96.66±5.77NS | 3.60±0.34 | 3.70±0.20 |
| 8 hour | 100.00NS | 100.00NS | 3.66±0.32 | 3.86±0.15 |

**Table 9. Dry weight of pea seedling on exposure to RF radiations from mobile phones**

| Time of exposure | Dry weight of seedling (g) | |
|---|---|---|
| | 2G phone | 3G phone |
| Control | 0.01±0.005 | 0.01±0.005 |
| ½ hour | 0.02±0.015 | 0.01±0.005 |
| 1 hour | 0.02±0.010 | 0.02±0.010 |
| 2 hour | 0.02±0.011 | 0.02±0.003 |

| | | |
|---|---|---|
| 4 hour | 0.01±0.011 | 0.03±0.017 |
| 8 hour | 0.03±0.010 | 0.02±0.005 |

**Conclusion**:

The study concluded that radiations emitted from mobile phone interfere with both morphological processes and affect the growth and nodule formation in the plants. The number of nodules developed both in Pisum sativum and Trigonella foenum graecum increases with increase in the radiation exposure.

**Fig. 5 Nodule formation in pea on exposure to RF radiations from mobile phones**

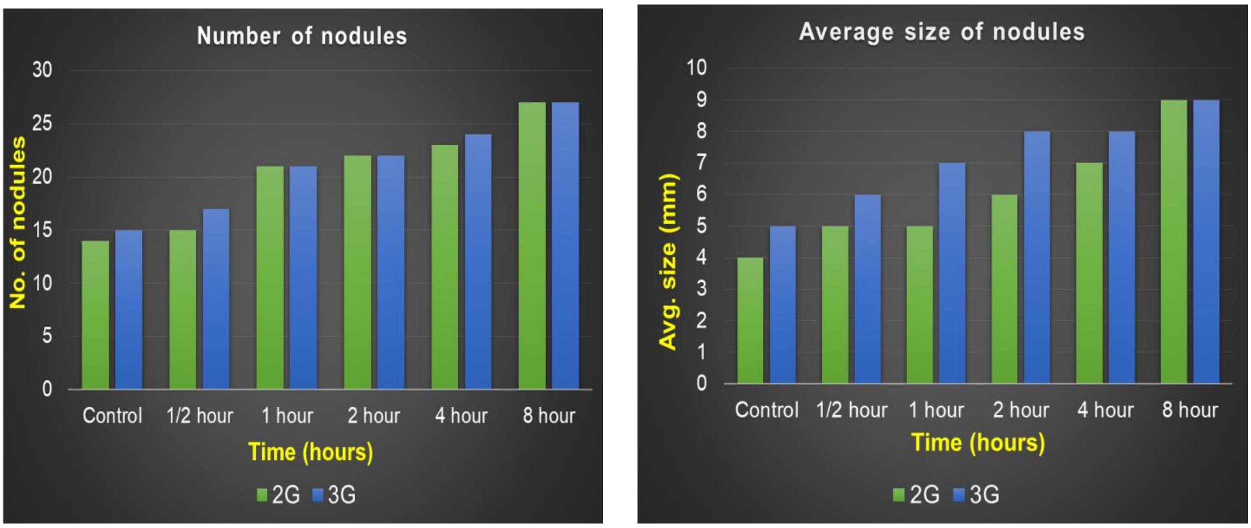
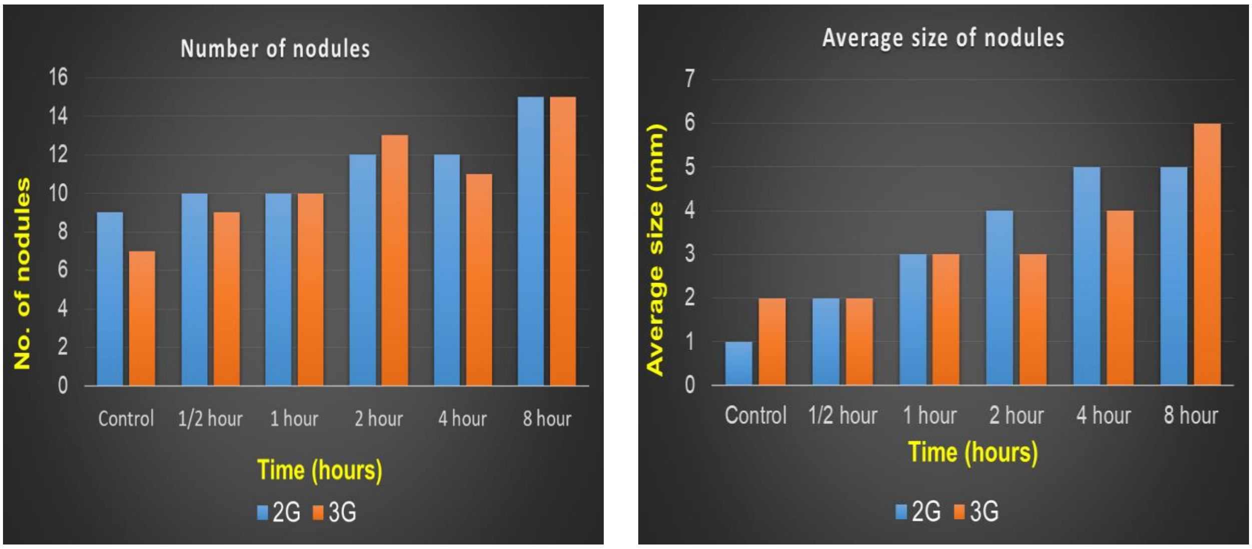



**Fig. 6 Nodule formation in fenugreek on exposure to RF radiations from mobile phones**



### 7.3.2 Impact of RF Electromagnetic Field on Cucumber and Tomato Plants (Kathiri et al., 2016)

The focus of the research work was to study the impact of fixed radio frequency and electromagnetic field exposures on cucumber and tomato plants growth/development and leaf membrane stability.

Three and four weeks older uniform seedlings of cucumber and tomato were transferred into treatment chambers. The experiment was carried out in controlled environment glass house at the Agriculture Experiment Station, College of Agriculture and Marine Sciences facility available at the Sultan Qaboos University. Humidity, lights, and temperature were controlled according to plant needs. Three set of experiments were laid out in parallel for cucumber and two sets for tomato.

In first experimental procedure, cucumber plants were placed in open controlled environment, where plants were exposed to open RF signals, which were being transmitted from the nearby cellular towers (Plate 13). The second set of experiment was established to isolate the plants as much from electro-magnetic waves or radio frequency signals to minimize any effect of the treatment. This was achieved by placing the plants in a box (59cm×54cm×54cm) that was fully wrapped with aluminium foil from all sides and then placing aluminium mesh on the top so the top of box (Plate 14). In the third set of experiments, plants were exposed to the maximum RF field environment, by directing a horn antenna with a frequency of 2.4 GHz directly to the plants. Similar to the second experiment, the plants were placed in a box of dimensions (59cm×54cm×54cm) that is fully wrapped with aluminium foil from all sides and then placing aluminium mesh on the top (Plate 15). Whereas, in tomato the protected and stressed environments were provided.

To measure the plant growth and development, cucumber plants were harvested after 5, 10 and 15 days of treatment, while tomato plants were harvested after 10 & 20 days of exposure. Plant fresh weight, total leaf numbers per plant and plant height were recorded at predetermined time intervals.

**Results:**

1. There were no significant differences observed in plant fresh weight, total leaf numbers and plant height at 5 days harvest. However, significant differences were recoded after 10 days (2nd harvest) & 15 days (third harvest) of continuous exposure to electromagnetic field. Results showed minimum plant fresh weight in plants exposed to RF environment in

case of cucumber. It revealed that prolonged exposure to electromagnetic field induced detrimental stress on cucumber plant growth and development.

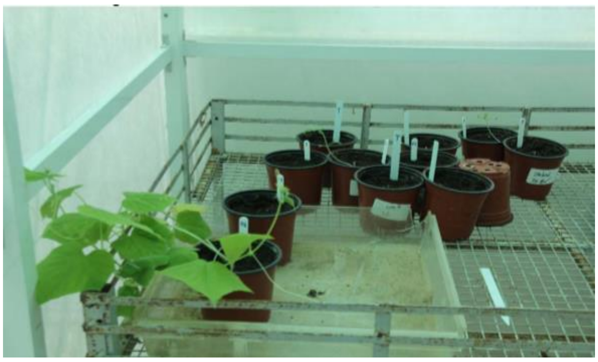


**Plate 14. Seedlings of cucumber under open environment**

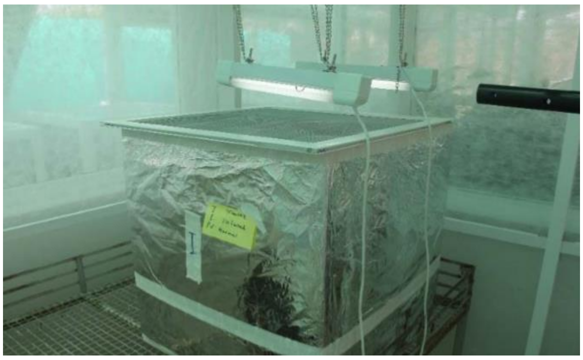


**Plate 15. Seedlings of cucumber under isolated condition**

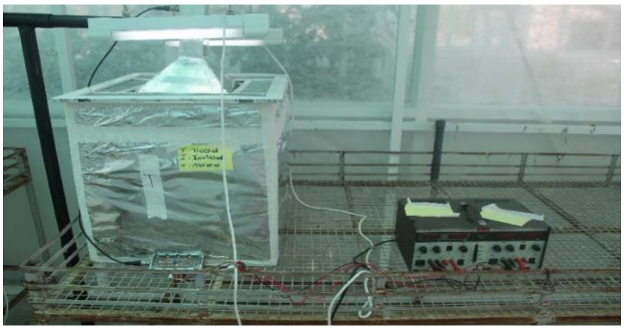


**Plate 16. Seedlings of cucumber under stressed condition**

**Fig.7 Plant growth and development in cucumber after 1st harvest**

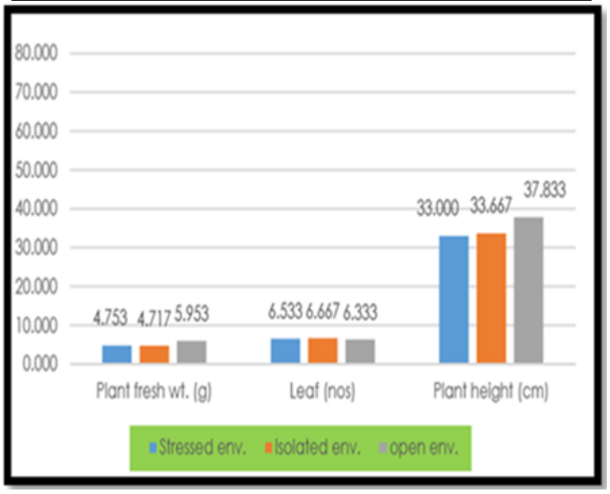



**Fig.8 Plant growth and development in cucumber after 2nd harvest**

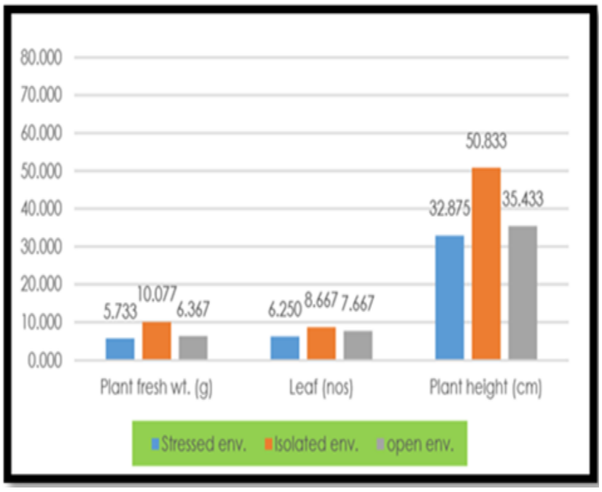


**Fig.9 Plant growth and development in cucumber after 3rd harvest**

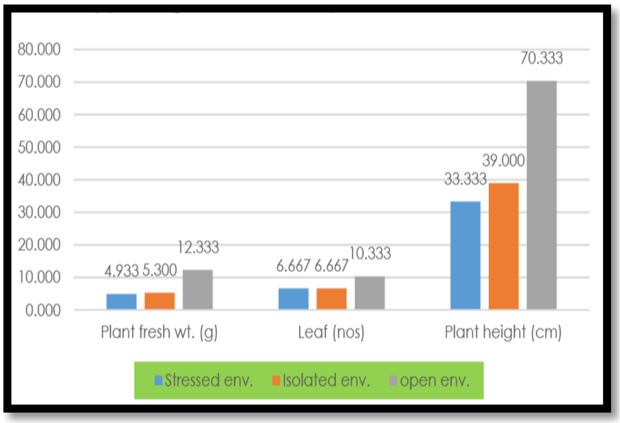



**Fig.10 Plant growth and development in tomato after 1st harvest**

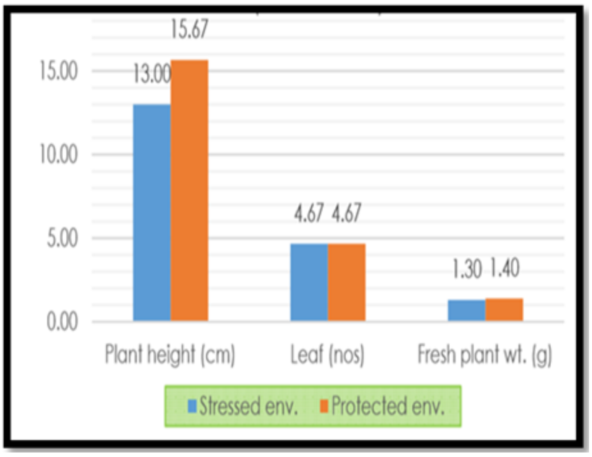
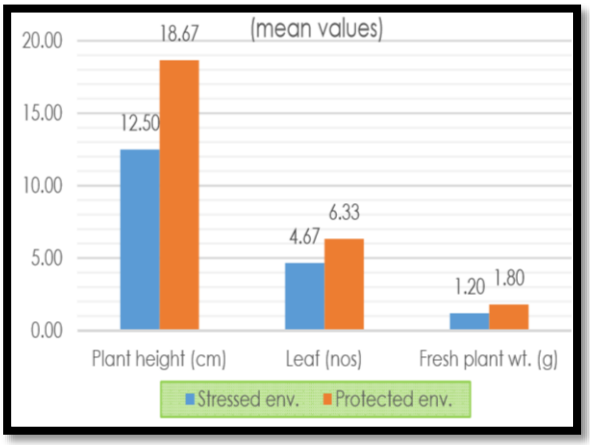



**Fig.11 Plant growth and development in tomato after 2nd harvest**




2. Contrasting studies on tomato plants did not show significant difference at first harvest. However, the differences in plant fresh weight, total leaf numbers and plant height were significant compared to first harvest.

**Conclusion:**

Overall results exhibited that the exposure to electromagnetic field treatment yielded a slightly stressed environment, which affected the cucumber and tomato plant growth and development. Higher electrolyte leakage coupled with reduced plant growth may be a function of free radical processes.

## 8. Conclusion

A consensus on how intense is the effect of RF radiations on human, animal and plant health, is yet to be reached. In today's world, wherein the Information technology (IT) revolution has integrated the entire world into a single cohesive global village, can man give up his dependence on RF radiation emitting communication devices?

**Man can choose to make-or-break the world!**

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## 10.Discussion:

1. **Which is the common mode of waves used for plant experiments?**

   Continuous wave (CW) mode is most commonly used than pulsed electromagnetic field (PEMF) mode.

2. **How we can achieve homogenous field in mode stirred reverberation chamber?**

   In mode stirred reverberation chamber (MSRC), due to the presence of rotating stirrer, which uniformly mixes the waves to create homogenous field.

3. **What is the function of MDA?**

   MDA is the product of lipid peroxidation and the amount of malondialdehyde (MDA) content will give the amount of lipid peroxidation or oxidative stress.

4. **What may be the reason for the decline in total protein?**

   It is not yet known whether the decrease in protein content results from an increase in protein degradation or a decrease in protein synthesis, but this may constitute a stimulating field of investigation.

5. **What is the role of stress proteins, that you have mentioned in tomato?**

   PinII gene, the protease inhibitor protect plants against insects and herbivores by reducing the digestibility and nutritional value of leaf protein and the lebZIP1 gene is involved in wound healing and self-defense in tomato plants

**KERALA AGRICULTURAL UNIVERSITY**

**COLLEGE OF HORTICULTURE, VELLANIKKARA**

**Department of Seed Science and Technology**

**SST 591: Masters' Seminar**


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|---|---|---|---|---|---|
| Name | : | Harshaprada, K. | Venue | : | Seminar Hall |
| Admission No. | : | 2018 - 11- 149 | Date | : | 16/01/2020 |
| Major Advisor | : | Dr. Rose Mary Francies | Time | : | 10.00 am |


## Are radiofrequency radiations crop friendly?

## Abstract


Radiofrequency-electromagnetic radiation (RF-EMR) or Radiofrequency Radiation (RFR) consists of waves of electric and magnetic energy moving together through space at the speed of light. These are non-ionizing radiations with a frequency ranging from 3 kilohertz (kHz) to 300 gigahertz (GHz). In the recent past Information technology (IT) has broken through geographical barriers and distance, integrating the entire world into a cohesive global village. The extremely rapid advancements in IT that has revolutionised communication is not without its fallout. The telecommunications devices such as radios, televisions, mobile phones, wireless networks like Wi-Fi and cordless phones, as well as satellite communications emit RF-EMR. Microwave ovens and radars are good examples of non-communication devices that emit RF-EMR energy.

In May 2011, the International Agency for Research on Cancer (IARC) classified RFR as a possible human carcinogen (Group 2B) (Hardell, 2017). In spite of such adverse findings, the usage of RFR emitting devices are on the rise. The market size of radiofrequency components globally grew by 14 per cent in 2019 from 18.06 billion USD in 2018. India also witnessed unprecedented growth in wireless data usage for communication and entertainment (TRAI, 2019).

A survey conducted at Dhing town of Assam indicated that there was a rapid decrease in the production of coconuts and betel-nut after the installation of mobile tower. It was also reported that the trees located within 50 meter radius of the cell phone tower were found to be feeble with dried tops (Debnath and Bora, 2015).

Plants are the outstanding models to conduct RF tests, as they are immobile, having high surface area to volume ratio and can perceive radiations of even small amplitudes (Roux et al., 2006). To analyse the effect of RF radiations small volume devices like Transverse Electromagnetic (TEM) cell, Gigahertz Transverse Electromagnetic (GTEM) cell and Mode Stirred Reverberation Chamber (MSRC) have been developed. The responses in plants to RF exposure may occur at morphological or at the subcellular level (biochemical and molecular response).

Liptai *et al*. (2017) studied the effect of Wi-Fi radiation on seed germination and plant growth in garden cress (*Lepidium sativum*). They observed that the germination of Wi-Fi exposed seed sample was less compared to the unexposed one. In addition, the number of withered plants in the exposed sample was high leading to lower seedling weight. In contrast, Sharma and Parihar (2014) found that radiation emitted from mobile phones resulted in an increase in germination per cent, seedling length and the number of nodules in *Pisum sativum* and *Trigonella foenum graecum.* In both the crops these growth parameters were also found to increase with an increase in the exposure period.

When mung bean and wheat seedlings were exposed to mobile phone radiation, the production of antioxidant enzymes like ascorbate peroxidase (APX), guaiacol peroxidase (GPX) and catalase (CAT) were found to increase. The melondialdehyde (MDA) content was high in stressed samples as compared to non-stressed plants proving that RF radiations induces oxidative stress, leading to increase in the activity of antioxidant enzymes and reduced growth (Afzal and Mansoor, 2012). The proline content in maize seedlings exposed to radiofrequency field of 940 MHz was elucidated to be high and the increase was found to be proportional to the exposure time (Zareh and Mohsenzadeh, 2015).

Alteration in gene expression has been reported on exposure to RF radiations. In tomato, exposure to radiation of frequency 1250 MHz was found to up-regulate the expression of genes coding for stress proteins like proteinase inhibitor (*pinII*) and *Lycospersicon esculentum* basic leucine Zipper1 (*lebZIP1*) and influenced their biological function (Rammal *et al*., 2014).

In spite of the uncertainty about the long-term effects of exposure to RF radiations on human, animal and plant health, several countries have formulated policies and issued health recommendations concerning exposure to RF. Can we judiciously slow down or abstain or restrain from relying on RF radiation emitting communication devices and technologies? This seems to be a million dollar question!

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