RESPONSE OF CORN (*ZEA MAYS*), BASIL (*OCIMUM BASILICUM*) AND EGGPLANT (*SOLANUM MELONGENA*) SEEDLINGS TO Wi-Fi RADIATION

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Abstract. The objective of the present study was to investigate the changes of growth related aspects of seedlings after being exposed to Wi-Fi radiation. Experiment was carried out by exposing seedlings to radiation from a Wi-Fi router. The test seedlings and the control were subjected to the same environment during four weeks. The results showed that corn seedlings when exposed to Wi-Fi radiation grew faster and have shoot length and stem thickness significantly larger than the other control. On the other hand basils and eggplants, both exposed and not exposed to Wi-Fi radiation, were found with no significant effects on the shoot length and stem thickness. Moreover Wi-Fi radiation significantly reduced the fresh weight of corns and basils, whereas eggplants were not affected. Furthermore Wi-Fi radiation significantly increased the dry weight of eggplants, whereas corns and basils were not affected. Finally, the results showed that Wi-Fi radiation significantly decreased the water content of three tested seedlings. The study concluded that the Wi-Fi radiation may alter growth related characters of seedlings.

Key words: Wi-Fi radiation, electromagnetic radiation, growth, corn, basil, eggplant seedlings.

INTRODUCTION

During the recent years, there has been an extensive increase in the usage of wireless devices which resulted in an increase of the exposure to electromagnetic radiations in our environment [3]. A router device is the most common telecommunication all over the world. Due to its advantages, this device has grown exponentially in recent years. Nowadays most of the population in the world use router device for communication. Like mobile phone, wireless router sends and receives information using radio waves, which are part of EMR with wavelengths longer than infrared light [33]. Radio waves have frequencies as high as 300 GHz

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to as low as 3 kHz and travel at the speed of light. We are surrounded by both artificial and natural EMR. Naturally occurring EMR are generated by lightning and astronomical objects. Artificially EMR are generated by communication satellites, computer networks, radio communication, broadcasting and radar [11]. The EMR in general and radiation emitted from the router in particular affect all living systems and influence cells, tissues and organs in different ways [4]. They affect, for instance, mammals [5], fruit flies [25], amphibians [3], ants [8], birds [13], bees [31] and even protozoa [7]. The impact of EMR on living organisms depends on the power level, frequency, exposure duration, pulsed or continuous wave and the properties of exposed tissue [2, 27].

Generally, radiations are known to induce ultrastructural, physiological, cytological and genetic modifications of the living cells [38]. The EMR act firstly on the cellular membrane and influence the activation of ions and the polarization of dipoles in living cells [7]. Such radiations have also been shown to impact plants at the cellular, molecular and whole plant scale. EMR is an important effective stress factor on the growth and development of plants [22]. Indeed, numerous metabolic activities are modified, gene expression altered and growth related characters changed after exposure to radiation. These changes occur not only in the tissues directly exposed to EMR but also in distant tissues [43]. Though the biological effects of EMR have drawn the attention of many scientists, yet there is lack of evidence of exact effects of Wi-Fi radiations on plants and their mechanism of action.

Of the thousands of articles on the biological effects of EMR, few studies on the effect of EMR on the growth of plants on the whole have been achieved. Special focus was paid on the effect of radiation on growth rate of plants after exposure of their seeds to the EMR. Despite these studies, the exact effect of EMR is still unclear, contradictory or underexamined. Some of the studies showed that the growth of plants under the effect of EMR was enhanced while others stated that the growth was inhibited.

The positive impact of EMR at low frequencies on the germination and growth of plants was mentioned in the study of Shine *et al.* [34], Isaac *et al*. [16] and Bilalis *et al*. [6]. They reported the simulative effect of the EMR on the development and morphological characteristics of the plants such as seed germination, shoot development, plant length, fresh weight, fruit production and fruit weight. According to Aladjadjiyan [1], EMR has a positive effect on the paramagnetic properties of some atoms in plant cells and pigments in them. The study of authors [10] stated that electromagnetic tomato seed treatment resulted in a significant increase in leaf area, leaf dry weight, the average weight of the fruits as well as an increase in harvest of tomatoes per unit area.

On the other hand, Soja *et al*. [37] in their study reported a reduction in corn and wheat yield in the fields near high tension lines. In studies of Tkalec *et al*. [39], they carried out an experiment to identify the physiological responses of duckweed

(*Lemna minor* L.) after exposure to EMR (900 MHz). The results showed that the EMR enhanced lipid peroxidation and increased hydrogen peroxide accumulation, thereby inducing oxidative stress and cellular damage [2, 30]. Also, Tkalec *et al.* [40] conducted an extensive study to investigate the effects of EMR on seed germination, primary root growth as well as mitotic activity and mitotic aberrations of *Allium cepa* L. meristematic cells. They revealed that the germination rate and root length were not changed significantly after exposure to EMR, but mitotic aberrations were significantly increased. The reason for the increase in the mitotic abnormalities may be explained with the impairment of the mitotic spindle following the application of electromagnetic fields.

Despite these studies, the exact effect of EMR in general, and of a Wi-Fi radiation in particular remains to be investigated. Since experiments on humans are very difficult, plants would be a better choice to study the overall effect of Wi-Fi radiation on growth and development of plants because plants are very sensitive to any changing in the environmental condition and response to their surrounding environment with high specificity [20]. In addition, plants are continuously exposed to various abiotic and biotic environmental stress [22].

The main objective of this experiment was to determine the effects of radiation from a Wi-Fi router, usually used in the home, on the growth of plants. Specifically the study aimed to determine the growth characteristics of corn, basil and eggplant seedlings which were exposed to and not exposed to Wi-Fi radiation with regard to: length of shoot, thickness of stem, fresh and dry weight, color, texture and number of leaves per seedling.

MATERIALS AND METHODS

The experiment was carried out in March 2017 for one month at the laboratories of biology and biotechnology, Faculty of Science, Islamic University of Gaza, Gaza Strip, Palestine, in order to investigate the effect of Wi-Fi radiation on the growth of plants.

PLANT MATERIAL

For the present study, two groups of seedlings were used and subjected to the study. The plant material was purchased locally from the market and divided into two groups. The first group of seedlings was exposed to Wi-Fi radiation while the other group was not exposed to Wi-Fi. Corn, basil and eggplant were used in this study. These seedlings were chosen because of their growth during the period of the present study as well as their ability to be cultivated in plastic pots. Moreover, these plants are considered one of the most important crops in Gaza Strip and the inhabitants plant it continuously in their homes. The tested seedlings were grown in plastic pots. The industrial soil (peat moss, SUBSTRATE SUB3 50/50, Nord Agri) without any addition was used, free of heavy metals. Throughout the experiment, the seedlings were not treated with any kind of pesticides. Table 1 illustrates number and distribution of seedlings in each group.

Table 1

The distribution of seedlings in each control and experimental groups.
The age of each seedling at the beginning of the experiment was one week

Type of seedlings	Number of seedlings in experimental group	Number of seedlings in control group
Corn	10	10
Eggplant	10	10
Basil	10	10
Total	30	30

TREATMENTS

Two experiments have investigated the effects of Wi-Fi radiation on seedlings. One set of seedlings was kept in control environment, whereas the other set was under conditions of the effect of Wi-Fi radiation. Exposure to Wi-Fi radiation was performed by using a router (Wavion WBS-2400 base station) (Fig. 1) that was plugged in 24 hours a day and it was not turned off. The frequency of that signal was 2.4 GHz. The distance between the router and seedlings was 50 cm. The reason for using this distance is that it is the most common distance between the router and the organisms in homes, whether human or plants. In the current study, we first began to study the effect of router on the plants and later we will study its impact on humans. Temperature ranged from 20–25 °C in the control and Wi-Fi exposed seedlings. Relative humidity ranged between 45–75% in both groups. All seedlings were irrigated with the same quality and quantity of water during the period of the present experiment.

MEASURING GROWTH RELATED CHARACTERISTICS

The seedlings were followed-up every week for one month with regard to the specific parameters. The following parameters were recorded:

1. shoot length (cm);
2. thickness of stem (cm);
3. color, texture and number of leaves per seedling;
4. fresh and dry weight per seedling (g).

The investigated parameters were chosen because they indicate the growth rate of plants under specific environmental conditions. Also, these parameters have been studied extensively in the previous experiments with regard to the impact of

EMR on the growth of plants. A ruler and capillary were used to measure the shoot length and stem thickness of each seedling respectively. Then at the end of the experiment, fresh weights of them were measured. Subsequently, they were dried in an oven at 60ºC for 48 hours and their dried weight was measured too. After this, the relative water content (*RWC*) was calculated by the formula [32]:

$$RWC = \frac{Fresh\ weight - Dry\ weight}{Fresh\ weight} \times 100 \quad (1)$$

Fig. 1. The router device that was used in the current experiment.

STATISTICAL ANALYSIS

Data were statistically analyzed using SPSS computer program version 22.0 for windows (Statistical Package for Social Sciences Inc, Chicago, Illinois). Graphs were plotted using Microsoft Excel program version 2010. In the case of normal distribution, a two-tailed Student's t-test was used to determine statistical significance ($\alpha = 0.05$) of the differences between experimental and control groups assuming equal variance. On the other hand, in the case of skewed distribution, a nonparametric test (Mann-Whitney Test) was used to determine the statistical significance of the differences between each two groups.

RESULTS

Possible effects upon Wi-Fi radiation emitted by the router devices were investigated by growth characteristic of each corn, basil and eggplant seedlings.

The first group of seedlings were exposed to Wi-Fi radiation for one month. The second group were not subjected to Wi-Fi radiation and used as control. Results are based on 10 seedlings of each species for each of two groups.

EFFECT OF Wi-Fi RADIATION ON SHOOT LENGTH

Table 2 illustrates an overview about the experimental results on the response of corns, basils and eggplants as exposed to and not exposed to Wi-Fi radiation with regard to length of shoots.

Table 2

The average of length (cm) for control and treated group

Plant	Exposed to Wi-Fi radiation		Not exposed to Wi-Fi radiation	
	Mean	SD	Mean	SD
Corn	17.02	1.67	7.82	1.48
Basil	22.02	4.21	24.64	4.36
Eggplant	5.55	2.36	5.06	1.36

The results revealed a significant difference (at $\alpha = 0.05$) in the length of seedlings among each corn group at the end of the experiment. Corn seedlings exposed to Wi-Fi radiation were significantly taller than the ones not exposed to Wi-Fi radiation. A different effect occurred between the basils which were exposed to and those not exposed to Wi-Fi radiation where the basil in the experimental group came to be shorter than those basils in the control group. This difference among each group in terms of seedling length was not significant (at $\alpha = 0.05$). Also, the table shows that there was almost a similar seedling length between the eggplant exposed and that not exposed to Wi-Fi radiation. This implies that Wi-Fi radiation has no effect on basils and eggplants with respect to the length of seedling.

EFFECT OF Wi-Fi RADIATION ON STEM THICKNESS

The results which are recorded in Table 3 show the effect of Wi-Fi radiation on the seedlings of corn, basil and eggplant with respect to the stem thickness.

Table 3

The average of stem thickness (cm) for control and treated group

Plant	Exposed to Wi-Fi radiation		Not exposed to Wi-Fi radiation	
	Mean	SD	Mean	SD
Corn	0.605	0.117	0.420	0.095
Basil	0.326	0.020	0.346	0.085
Eggplant	0.292	0.046	0.264	0.069

As revealed on the previous table, the results showed that the stem thickness of corns exposed to Wi-Fi radiation is significantly bigger than those which were not exposed to Wi-Fi radiation. On the other hand, basils exposed to Wi-Fi radiation have a thickness shorter than that of those which were not exposed to Wi-Fi radiation. This difference among each basil group in terms of stem thickness was not significant ($\alpha = 0.05$). In addition, the results which are presented in Table 3 showed that the stem thickness of eggplant was not significantly increased when exposed to the router devices. Just like in seedling length, Wi-Fi radiation seemed not to have influence on stem thickness of either basil or eggplant exposed or not exposed to Wi-Fi radiation.

EFFECT OF Wi-Fi RADIATION ON THE NUMBER OF LEAVES

The results in Table 4 illustrate the effect of Wi-Fi radiation on leaves number for each tested seedlings.

Table 4

The average of leaves number for control and treated group

Plant	Exposed to Wi-Fi radiation		Not exposed to Wi-Fi radiation	
	Mean	SD	Mean	SD
Corn	6	0.57	6	0.48
Basil	39	11	32	6.34
Eggplant	5	0.95	5	1.58

Analysis of these results revealed that the leaves of basil exposed to Wi-Fi radiation were more in number compared to those that were not exposed. Such difference observed between the two basil groups was not significant (at $\alpha = 0.05$). In the case of corns and eggplants, both exposed and not exposed to Wi-Fi radiation, they have almost the same number of leaves.

EFFECT OF Wi-Fi RADIATION ON LEAVES MORPHOLOGY

In the morphological analysis of each tested seedling, different changes were observed among exposed seedlings in comparison to control ones with respect to morphology of leaves. At the beginning of the experiment and after 7 days, no different changes were observed, but after 14 days, different changes were observed in terms of color and texture of leaves. Table 5 illustrates the effects of Wi-Fi radiation on leaves morphology with regard to texture and color of leaves. It could be gleaned that the leaves of seedlings that were exposed to Wi-Fi radiation had a color of dark green and their texture was rough as compared to controls which manifested a pale green.

Table 5

Effects of Wi-Fi radiation on leaves morphology for control and treated group

Plant	Exposed to Wi-Fi radiation		Not exposed to Wi-Fi radiation	
	Color	Texture	Color	Texture
Corn	Dark green	Rough	Pale green	Smooth
Basil	Dark green	Rough	Pale green	Smooth
Eggplant	Dark green	Rough	Pale green	Smooth

EFFECT OF Wi-Fi RADIATION ON FRESH AND DRY WEIGHT

The results in Table 6 show the effect of Wi-Fi radiation on fresh weight (FW) and dry weight (DW) for each tested seedling.

Table 6

Effects of Wi-Fi radiation on fresh and dry weight for control and treated group

Plant	Exposed to Wi-Fi radiation				Not Exposed to Wi-Fi radiation			
	FW (g)		DW (g)		FW (g)		DW (g)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Corn	5.56	2.24	1.56	0.46	12.55	4.01	1.69	0.51
Basil	4.56	1.36	1.97	0.54	10.74	2.31	1.83	0.64
Eggplant	1.52	0.60	0.59	0.23	1.30	0.42	0.19	0.06

As reflected from the table, the results indicated that Wi-Fi radiation significantly reduced the FW of corn and basil seedlings, whereas eggplant was not affected after exposure to Wi-Fi. With regards to DW, the results illustrated that Wi-Fi radiation significantly increased the DW of eggplants, whereas corns and basils were not affected after exposure to Wi-Fi.

EFFECT OF Wi-Fi RADIATION ON THE NATURE OF SOIL

Although both groups were irrigated with the same amount of water at the same time, however, it was observed that the soil in the case of the experimental group was drier than the soil of those which were not exposed to Wi-Fi radiation.

EFFECT OF Wi-Fi RADIATION ON RELATIVE WATER CONTENT

The results in Table 7 show the effect of Wi-Fi radiation on the relative water content (RWC) for each tested species.

Table 7

Effects of Wi-Fi radiation on the relative water content (%) for control and treated group

Plant	Exposed to Wi-Fi radiation		Not exposed to Wi-Fi radiation	
	Mean	SD	Mean	SD
Corn	67.48	10.09	86.36	1.97
Basil	55.58	11.69	82.71	6.63
Eggplant	56.86	18.7	84.44	3.91

As reflected from the previous table, it could be concluded that a Wi-Fi radiation significantly decreased the relative water content of each corn, basil and eggplant seedling.

DISCUSSION

The current study was conducted to explore the effect of Wi-Fi radiation emitted from the router devices on the growth and development of each corn, basil and eggplant seedlings. The study found out that the Wi-Fi radiation causes changes in the morphology of seedlings. Exposure of seedlings to Wi-Fi radiation may significantly alter growth related characters such as shoot length, stem thickness, dry and fresh weight, color and texture of leaves. Of the three species we tested, eggplants seemed to be the least responsive to Wi-Fi radiation whereas corns were the most responsive under laboratory conditions. It was noticed that the corn seedlings grown near the router devices recorded the highest in both shoot length and stem thickness as compared to those of the control. The study concluded that corn seedlings when exposed to Wi-Fi radiation grew faster and had shoot length and stem thickness significantly bigger than the corns not exposed to Wi-Fi radiation. On the other hand, basils and eggplants, both exposed and not exposed to Wi-Fi radiation, were found with no significant effects on their growth characteristics such as shoot length and stem thickness.

Such enhanced growth of exposure of corn seedlings was reported previously by Shabrangi and Majd [29], who showed that the EMR can affect developmental growth characteristics of plants when exposed their seeds to EMR. The authors found that suitable EMR could speed up seedling development and increase the biomass. They observed an overall stimulating effect of EMR on corn with respect to growth characteristics. According to Vashisth and Nagarajan [42], they noted that there is a significant increase in germination, seedling vigor and shoot growth in corn and chickpea seeds exposed to EMR. Similar observations have also been reported in rice [9], in barley and wheat after exposure the seeds of these plants to magnetic field [23, 24] and in radish, carrot, and tomato after exposure of the seeds of these plants to high power EMR [26]. In addition, Khalafallah and Sallam [17] showed that germination of corn grains and growth of seedlings was significantly activated when exposed to microwave radiation emitted from the cellular phone comparing to control ones. The reasons standing behind the accelerated growth were found to be similar to the reasons reported by other studies [43, 15]. They mentioned the EMR effect on the stimulation, modification, alterations or activation of gene regulation and expression, biochemical processes and enzymatic activities at the level of seeds or the whole plant [43].

Furthermore, the current study revealed that the Wi-Fi radiation has no effect on eggplant seedlings related to seedling length, stem thickness and leaves number. Similarly these findings were in agreement with Rio and Rio [28]. They revealed that eggplants exposed and not exposed to EMR have no significant differences on their height, length and basal diameter.

On the contrary, the present results disagree with that of Kumar *et al*. [18], who demonstrated that EMR significantly decline the seedlings length of corn, particularly at higher exposure periods of 2 and 4 h. Similarly, Havas and Symington [14] found that radiation from Wi-Fi router reduces shoot growth of broccoli, pea and red clover after exposure of the seeds of these plants to Wi-Fi radiation. Such a reduction in seedling length on exposure to EMR was also corroborated by similar findings made earlier with cell phone radiations [30] and radiofrequency EMR [2, 40].

In the present study, Wi-Fi radiation significantly reduced the fresh weight of corns and basils, whereas eggplants were not affected. Also Wi-Fi radiation significantly increased the dry weight of eggplants, whereas corns and basils were not affected. The results also showed that Wi-Fi radiation significantly decreased the water content of three tested seedlings. Such a reduction in fresh weight and increase in dry weight was documented by similar findings made earlier with cell phone radiations [27, 32]. They reported that the mobile phone radiations significantly decreased the fresh weight and increased the dry weight of Pea (*Pisum sativum)* and Fenugreek *(Trigonella foenumgraecum)* after exposure of their seeds to mobile phone radiations. Furthermore, results of the present study were found parallel to those of Majd *et al*. [22] for *Satureja bachtiarica* L. They observed a significant decrease in fresh weight of treatment samples after exposure their seeds to low frequency EMR in comparison to control. On the other hand, the same authors also found a significant decrease in dry weight after exposure of the seeds of the previous plants to EMR at low frequency.

Regarding the color of leaves, our results showed a positive effect on leaves color of those seedlings that were exposed to Wi-Fi radiation. The leaves of seedlings exposed to Wi-Fi were more greenish than those of the control. These differences may be due to different levels of chlorophyll content and other pigments among each group. These findings seem to coincide with that stated by Khalafallah and Sallam [17] and Aladjadjiyan [1]. They mentioned that photosynthetic pigments were positively affected by EMR exposure. In the study of Lebedev *et al*. [19], the authors proved that suitable EMR increased photochemical activities in a unit of chlorophyll molecule resulting in an increase in the green pigment of wheat, bean [21] and soybean [34]. The results are also in accordance with an earlier study of Isaac *et al.* [16] who observed an increase in the concentration of chlorophyll a, chlorophyll b and carotene in corn seedlings obtained from seeds treated electromagnetically. The reasons standing behind increased photochemical and photosynthetic activities in treated leaves were found to be similar to the reasons mentioned by other studies [35]. In leaves, the content of reactive oxygen species is lower after treatment with EMR and this is accompanied by higher photosynthetic efficiency of leaves.

On the other hand, different results have been stated by Ursache *et al.* [41], Kumar *et al.* [18] and Vian *et al.* [43]. They reported that exposure of maize seedlings to EMR at specific frequency caused a drop in total carotene, chlorophyll a and chlorophyll b content. These modifications due to abnormal photosynthetic activity rely on many parameters, including chlorophyll and carotenoid content [43].

With regard to the effect of Wi-Fi radiation on leaves number, the results indicated that both seedlings exposed and not exposed to Wi-Fi radiation have almost the same number of leaves per seedling. These results differ from those obtained by El-Gizawy *et al.* [12] who reported that the potato plants which were treated by MF (30 mT) for 10 minutes produced the highest significant values for number of leaves per plant.

CONCLUSIONS

In this experiment, we investigated the effect of Wi-Fi radiations on the growth of corn, basil and eggplant seedlings. We found that:

1. Wi-Fi radiation had a stimulatory effect on growth characteristics of corn plants. Corns when exposed to Wi-Fi radiation grow faster and have shoot length and stem thickness significantly bigger than the seedlings not exposed to Wi-Fi radiation.
2. The study revealed that basils and eggplants exposed and not exposed to Wi-Fi radiation have no significant differences on their shoot length and stem thickness of seedlings.
3. The study proved that the tested seedlings that were exposed to Wi-Fi radiation had a color of dark green and their texture was rough in comparison to that of the control. On the other hand, in the case of control seedlings, the leaves had a color of pale green. Also, seedlings that were

not exposed to Wi-Fi radiation have a smoother texture than the texture of those which were exposed to.

4. The results indicated that Wi-Fi radiation significantly reduced the fresh weight of corns and basils, whereas eggplants were not affected.
5. Also Wi-Fi radiation significantly increased the dry weight of eggplants whereas, corns and basils were not affected.
6. Furthermore, the results showed that Wi-Fi radiation significantly decreased the relative water content of the three tested seedlings.

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REFERENCES

1. ALADJADJIYAN, A., Influence of stationary magnetic field on lentil seeds, *International Agrophys*ics, 2010, **24**, 321–324.
2. AKBAL, A., Y. KIRAN, D. TURGUT-BALIK, A. SAHIN, H. BALIK, Effects of electromagnetic waves emitted by mobile phones on germination, root growth, and root tip cell mitotic division of *Lens culinaris*, *Medik*. *Polish Journal of Environmental Studies*, 2012, **21**, 23–29.
3. BALMORI, A., The incidence of electromagnetic pollution on the amphibian decline: Is this an important piece of the puzzle? *Toxicology and Environmental Chemistry*, 2006, **88**, 287–299.
4. BELYAVSKAYA, N.A., Biological effects due to weak magnetic field on plants, *Advances in Space Research*, 2004, **34**, 1566–1574.
5. BENLAIDI, F.Z., M. EL KHARROUSSi, Effets des ondes electromagnetiques génerées par le GSM sur la mémoire et le comportement chez le rat, *Journal of plant physiology*, 2011, **2**, 149–156.
6. BILALIS, D.J., N. KATSENIOS, A. EFTHIMIADOU, A. KARKANIS, E.M. KHAH, T. MITSIS, Magnetic field pre-sowing treatment as an organic friendly technique to promote plant growth and chemical elements accumulation in early stages of cotton, *Australian Journal of Crop Science*, 2013, **7**(1), 46–50.
7. CAMMAERTS, M.C., O. DEBEIR, R. CAMMAERTS, Changes in *Paramecium caudatum* (protozoa) near a switched-on GSM telephone, *Electromagnetic Biology and Medicine*, 2011, **30**, 57–66.
8. CAMMAERTS, M.C., Z. RACHIDI, F. BELLENS, P. DE DONCKER, Food collection and responses to pheromones in an ant species exposed to electromagnetic radiation, *Electromagnetic Biology and Medicine*, 2013, **10**, 1–18.
9. CARBONELL M.V., E. MARTINEZ, J.M. AMAYA Stimulation of germination in rice (*Oryza savita* L.) by a static magnetic field, *Electro- and Magnetobiol*ogy, 2000, **19**, 121–128.
10. DE SOUZA, A., Pre-sowing magnetic treatments of tomato seeds increase the growth and yield of plants. *Bioelectromagnet*., 2006, **27**, 247–257.
11. DICKINSON, D., *Industrial Wireless Technology*, Phoenix Contact, 2006.

12. EL-GIZAWY, A.M., M.E. RAGAB, N.A. HELAL, A. EL-SATAR, I.H. OSMAN, Effect of magnetic field treatments on germination of true potato seeds, seedlings growth and potato tubers characteristics, *Middle East Journal of Agriculture Research*, 2016, **5**, 1–8.
13. EVERAERT, J., D. BAUWENS, A possible effect of electromagnetic radiation from mobile phone base stations on the number of breeding house sparrows (*Passer domesticus*), *Electromagnetic Biology and Medicine*, 2007, **26**, 63–72.
14. HAVAS, M., M. SYMINGTON, Effects of Wi-Fi radiation on germination and growth of broccoli, pea, red clover and garden cress seedlings: A partial replication study, *Current Chemical Biology*, 2016, **10**, 65–73.
15. INOZEMCEV, G.B., Impact of electromagnetic energy on the increasing yield capacity and growth stimulation of plants, *Annals of Warsaw University of Life Sciences – SGGW, Agriculture,* 2013, **62**, 31–35.
16. ISAAC, A., A. HERNÁNDEZ, A. DOMÍNGUEZ, O. CRUZ, Effect of pre-sowing electromagnetic treatment on seed germination and seedling growth in maize (*Zea mays* L.), *Agronomía Colombiana*, 2011, **29**, 405–411.
17. KHALAFALLAH, A.A., S.M. SALLAM, Response of maize seedlings to microwaves at 945 MHz, *Romanian J. Biophys.*, 2009, **19**, 49–62.
18. KUMAR, A., H.P. SINGH, D.R. BATISH, S. KAUR, R.K. KOHLI, EMF radiations (1800 MHz) inhibited early seedling growth of maize (*Zea mays* L.), *Protoplasma*, 2016, **253**, 1043–1049.
19. LEBEDEV, I.S., L.G. LITVINENKO, L.T. SHIYAN, After effect of a permanent magnetic field on photochemical activity of chloroplasts, *Soviet Plant Physiology*, 1977, **24**, 394–395.
20. LIPTAI, P., B. DOLNIK, V. GUMANOVA, Effect of Wi-Fi radiation on seed germination and plant growth-experiment, *Annals of the Faculty of Engineering Hunedoara*, 2017, **15**(1), 109–112.
21. MAEDA, H., *Do the Living Things Feel the Magnetism*?, Kodansha, Kodansha Press, Tokyo, Japan, 1993.
22. MAJD, A., T. NEJADSATTARI, S. ARBABIAN, Study of effects of extremely low frequency electromagnetic radiation on biochemical changes in *Satureja bachtiarica* L., *International Journal of Scientific & Technology Research*, 2012, **1**, 77–82.
23. MARTINEZ, E., M.V. CARBONELL, J.M. AMAYA, A static magnetic field of 125 mT stimulates the initial growth stages of barley (*Hordeum vulgare* L.), *Electro- and magnetobiology*, 2000, **19**, 271–277.
24. MARTINEZ, E., M.V. CARBONELL, M. FLOREZ, Magnetic biostimulation of initial growth stages of wheat (*Triticum aestivum,* L.), *Electromagnetic Biology and Medicine*, 2002, **21**, 43–53.
25. PANAGOPOULOS, D.J., Gametogenesis, embryonic and postembryonic development of *Drosophila melanogaster*, as a model system for the assessment of radiation and environmental genotoxicity, In: M. Spindler-Barth (ed.), *Drosophila melanogaster*: *life cycle, genetics and development*, Nova Science Publishers, Inc, New York, USA, 2012, pp. 1–38.
26. RADZEVIČIUS, A., S. SAKALAUSKIENE, M. DAGYS, R. SIMNIŠKIS, R. KARKLELIENE, Č. BOBINAS, P. DUCHOVSKIS, The effect of strong microwave electric field radiation on vegetable seed germination and seedling growth rate, *Zemdirbyste-Agriculture*, 2013, **100**, 179–184.
27. RAGHA, L., S. MISHRA, V. RAMACHANDRAN, M.S. BHATIA, Effects of low-power microwave fields on seed germination and growth rate, *Journal of Electromagnetic Analysis and Applications*, 2011, **3**, 165–171.
28. RIO, L.C., M.M. RIO, Effect of electromagnetic field on the growth characteristics of okra (*Abelmoschus esculentus*), tomato (*Solanum lycopersicum*) and eggplant (*Solanum melongena*). *International Journal of Scientific and Research Publications*, 2013**, 3**, 1–9.

29. SHABRANGI, A., A. MAJD, Comparing effects of electromagnetic fields (60 Hz) on seed germination and seedling development in monocotyledons and dicotyledons, *PIERS Proceedings*, 2009, **18**, 704–709.
30. SHARMA, V.P., H.P. SINGH, R.K. KOHLI, D.R. BATISH, Mobile phone radiation inhibits *Vigna radiata* (mung bean) root growth by inducing oxidative stress, *Science of The Total Environment*, 2009, **407**, 5543–5547.
31. SHARMA, V. P., N.R. KUMAR, Changes in honeybee behavior and biology under the influence of cell phone radiations, *Current Science* (Bangalore), 2010, **98**, 1376–1378.
32. SHARMA, S., L. PARIHAR, Effect of mobile phone radiation on nodule formation in the leguminous plants, *Current World Environment*, 2014, **9**, 145–155.
33. SHENDE, V.A., K.G. PATIL, Electromagnetic radiations: A possible impact on population of house sparrow (*Passer domesticus*), *Engineering International*, 2016, **3**, 45–52.
34. SHINE, M.B., K.N. GURUPRASAD, A. ANAND, Enhancement of germination, growth, and photosynthesis in soybean by pretreatment of seeds with magnetic field, *Bioelectromagnetics*, 2011, **32**, 474–484.
35. SHINE, M.B., K. N. GURUPRASAD, A. ANAND, Effect of stationary magnetic field strengths of 150 and 200 mT on reactive oxygen species production in soybean, *Bioelectromagnetics*, 2012, **33**, 428–437.
36. SINGH, H.P., V.P. SHARMA, Electromagnetic radiations from cell phone inhibit plant root growth through induction of oxidative damage, *Epidemiology*, 2011, **22**, S249–252.
37. SOJA, G., B. KUNSCH, M. GERZABEK, T. REICHENAUER, A.M. SOJA, G. RIPPAR, H.R. BOLHAR-NORDENKAMPF, Growth and yield of winter wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.) near a high voltage transmission line, *Bioelectromagnetics*, 2003, **24**, 91–102.
38. TAFFOREAU, M., M.C. VERDUS, V. NORRIS, C. RIPOLL, M. THELLIER, Memory processes in the response of plants to environmental signals, *Plant signaling & behavior*, 2006, **1**, 9–14.
39. TKALEC, M., K. MALARIĆ, B. PEVALEK-KOZLINA, Exposure to radiofrequency radiation induces oxidative stress in duckweed (*Lemna minor* L.), *Science of the Total Environment*, 2007, **388**, 78–89.
40. TKALEC, M., K. MALARIĆ, M. PAVLICA, B. PEVALEK-KOZLINA, & Ž. VIDAKOVIĆ-CIFREK, Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of *Allium cepa* L., *Mutation Research / Genetic Toxicology and Environmental Mutagenesis*, 2009, **672**(2), 76–81.
41. URSACHE, M., G. MÎNDRU, D.E. CREANGĂ, F.M. TUFESCU, C. GOICEANU, The effects of high frequency electromagnetic waves on the vegetal organisms, *Romanian Journal of Physiology*, 2009, **54**, 133–145.
42. VASHISTH, A., S. NAGARAJAN, Effect of pre-sowing exposure to static magnetic field of maize (*Zea mays* L.) seeds on germination and early growth characteristics, *Pusa Agriscience*, 2007, **30**, 48–55.
43. VIAN, A., E. DAVIES, M. GENDRAUD, P. BONNET, Plant responses to high frequency electromagnetic fields, *Hindawi Publishing Corporation BioMed Research International*, 2016, 1–14, ID 1830262, http://dx.doi.org/10.1155/2016/1830262.