How does Wi-Fi radiation affect the growth of plants?

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1. Introduction

Recently, my mother has been sharing links and articles on social networks, a large part of which are about the alarming dangers that radiation of sources such as Wi-Fi present to our health. Because of this, she prefers to disconnect her phone and computer from the network at night. My father, on the other hand, is not so worried about this apparent issue, and he believes that these so-called "studies" are highly exaggerated.

Being a technology fan, I decided to do some research on this subject. After searching the internet, it seemed to me that a considerable amount of people and various studies support these claims about Wi-Fi's detrimental effects,[1] while another part of the scientific community disregards the issue, attributing the stated symptoms to the placebo effect or other illnesses.[2] However, I couldn't fail to notice that studies against the widespread usage of Wi-Fi tend to be related to alternative medicine, or even written by people who directly profit from the sale of radiation-blocking products, as is the case with companies like EarthCalm, which both make claims about Wi-Fi being dangerous and at the same time sell products that are advertised as radiation-protecting.[3] On the other hand, it has been found that some studies proving that Wi-Fi has no detrimental effects at all could be sponsored by, or that some organizations or key people advocating this could be related to or even bribed by technology corporations which benefit from the sale of Wi-Fi products.[4]

Because of the vagueness around this issue, I decided to study the adverse effects of Wi-Fi radiation myself. This will be done by fulfilling the following two goals, which outline the purpose of this essay:

1. Performing a brief theoretical investigation in order to find out whether or not Wi-Fi radiation could potentially be harmful to life forms; and
2. Performing a practical experiment on plants in order to study the effects Wi-Fi waves have on them, and comparing these results with those of the initial investigation.

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[1] Szczerba, Robert J. "Controversial Study Suggests Wi-Fi Exposure More Dangerous To Kids Than Previously Thought." *Forbes*. N.p., 13 Jan. 2015. Web. 24 Mar. 2016.

[2] Billington, James. "Reality Check: No, Your Wi-Fi Isn't Dangerous." *Alphr*. Dennis Publishing, 18 July 2015. Web. 14 Aug. 2016.

[3] Frazier, Vidya. "How to Avoid WiFi Radiation Health Risks." *EarthCalm*. N.p., 27 May 2014. Web. 7 Sept. 2016.

[4] PSRAST. "Mobile Phone Safety." *Physicians and Scientists for Responsible Application of Science and Technology*. N.p., 7 Dec. 2014. Web. 7 Sept. 2016.

The theoretical investigation will focus on the various types of electromagnetic radiation, including Wi-Fi and their respective harmfulness or harmlessness, and is detailed in section 2. The practical experiment, as detailed in sections 3 and 4, will be carried out by using a Wi-Fi router, as found in many buildings nowadays, and a number of spearmint (*Mentha spicata*) seeds, to monitor the differences in the growth of these plants caused by proximity to the router. If the effects of Wi-Fi on humans are as grave as some studies claim, they should be visible in plants as well, especially since it has been claimed multiple times that plants do not grow as well in proximity to a Wi-Fi router, like in a 2013 primary school experiment in Denmark.[5] Finally, these results will be related to the theoretical investigation.

[5] Bean, Daniel. "Can WiFi Signals Stunt Plant Growth?" *ABC News*. ABC News Network, 24 May 2013. Web. 09 Aug. 2016.

2. Electromagnetic radiation in everyday life

In an urban environment, various types of electromagnetic radiation are almost perpetually present, both from natural and man-made sources. These types of radiation are distinguished by the amount of energy possessed by the photons which form them – their photon energy – and their wavelength.

2.1. Harmfulness of electromagnetic radiation

The electromagnetic spectrum

Electromagnetic radiation appears in various forms, these differenced by their frequency and wavelength.[6] Some of these kinds of radiation are ionising, which means that their energy is high enough to ionise atoms or molecules. This effect is harmful and even lethal to living tissue such as animals and plants.[7] The boundary between ionising and non-ionising radiation, as indicated by its photon energy, is not well-defined, as ionisation energy varies between different atoms and molecules, though the minimum is placed around $E = 10\ eV$.[8] While the most dangerous variants of natural radiation – these being the ones with the shortest wavelength and the highest energy: gamma rays, x-rays, and ultraviolet light – are blocked by the Earth's atmosphere, they can appear under other circumstances

Gamma radiation

For instance, gamma radiation, which on Earth can be found in radioactive decay processes and nuclear explosions,[9] has the smallest average wavelength of approximately

[6] Patel, Nikita, Kevin Vo, and Mateo Hernandez. "Electromagnetic Radiation." *LibreTexts*. UC Davis, 19 Sept. 2015. Web. 7 Sept. 2016.

[7] WHO. "What Is Ionizing Radiation?" *World Health Organization*. N.p., n.d. Web. 6 Sept. 2016.

[8] Cleveland, Robert F., Jr., and Jerry L. Ulcek. "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields." *OET BULLETIN 56* (1999): n. pag. *FCC.gov*. FCC Office of Engineering and Technology. Web. 6 Sept. 2016.

[9] NASA Science Mission Directorate. "Gamma Rays." *Mission:Science*. National Aeronautics and Space Administration, 2010. Web. 14 Aug. 2016.

$\lambda = 1pm$. According to the equation of photon energy $E = \frac{h*c}{\lambda}$, where E is photon energy, h is the Planck constant, c is the speed of light and λ is the wavelength,[10] its energy is:

$$E = \frac{4.135667662 * 10^{-15} eV * s * 299792458\, m/s}{10^{-12} m} \approx 1.24 * 10^{6}\ eV$$

This is much above the limit described even at its maximum wavelength. Because of this, exposure to even low levels of gamma radiation leads to radiation poisoning, illness, or death.

X-radiation

X-radiation, with wavelength of $\lambda = 100pm$ at most, on the other hand, has useful purposes in small and controlled amounts, such as in x-ray photography.[11] However, its photon energy is the following:

$$E = \frac{4.135667662 * 10^{-15} eV * s * 299792458\, m/s}{10^{-10} m} \approx 1.24 * 10^{4}\ eV$$

This is still much above the boundary between ionising and non-ionising radiation. Because of this, when exposed to x-rays for longer duration, or in excess and without protection, however, these can be carcinogenic.

Ultraviolet light

The wavelength of ultraviolet light, which is invisible to the human eye, ranges between approximately $\lambda = 100nm$ and $\lambda = 400nm$,[12] which gives these waves a photon energy between the following two values, respectively:

$$E = \frac{4.135667662 * 10^{-15} eV * s * 299792458\, m/s}{10^{-7} m} \approx 1.24 * 10\ eV$$

$$E = \frac{4.135667662 * 10^{-15} eV * s * 299792458\, m/s}{4 * 10^{-7} m} \approx 3.10\ eV$$

[10] Honsberg, Christiana, and Stuart Bowden. "Energy of Photon." *PV Education*. N.p., n.d. Web. 6 Sept. 2016.

[11] NASA Science Mission Directorate. "X-Rays." *Mission:Science*. NASA, 2010. Web. 14 Aug. 2016.

[12] NASA Science Mission Directorate. "Ultraviolet Waves." *Mission:Science*. NASA, 2010. Web. 14 Aug. 2016.

Since the limit between ionising and non-ionising radiation is around $E = 10\,eV$, as described earlier, ultraviolet light encompasses both types of radiation. According to wavelength, this type of radiation is classified from least harmful to most in UV-A, UV-B and UV-C. The latter is completely absorbed by Earth's atmosphere, but is dangerous and may be carcinogenic.[13] and the light that does reach the Earth's surface, such as UV-A, can cause sunburn and other health issues. Even so, exposure to sunlight – containing ultraviolet light – has its benefits, such as increase in vitamin D production.[14]

Visible light

Electromagnetic waves with wavelength between $\lambda = 400nm$ and $\lambda = 700nm$ can be seen by the human eye, and are known as visible light.[15] Visible light is below the boundary of ionising radiation, and besides being able to cause sight damage after extreme exposure, has apparent beneficial or detrimental effects.[16]

Infrared light

Just like ultraviolet light has a slightly shorter wavelength than visible light, infrared light has a longer wavelength than visible light, between $\lambda = 700nm$ and $\lambda = 1mm$. This type of radiation appears in the form of thermal energy and has various applications, ranging from thermal imaging to heat lamps and remote control signals.[17] Just like visible light, infrared radiation is non-ionising and, as a result, is unable to cause harm in the same way gamma radiation or x-radiation do. Even so, the heat generated by infrared light can cause burns in

[13] National Toxicology Program. "Report on Carcinogens, Thirteenth Edition." *National Toxicology Program*. U.S. Department of Health and Human Services, 2014. Web. 7 Sept. 2016.

[14] Cancer Council Australia. "Position Statement - Sun Exposure and Vitamin D - Risks and Benefits." *National Cancer Control Policy*. Cancer Council Australia, 3 Oct. 2010. Web. 7 Sept. 2016.

[15] NASA Science Mission Directorate. "Visible Light." *Mission:Science*. NASA, 2010. Web. 14 Aug. 2016.

[16] Scientific Committee on Emerging and Newly Identified Health Risks. "Health Effects of Artificial Light." *Europa.eu*. Scientific Committee on Emerging and Newly Identified Health Risks, 19 Mar. 2012. Web. 7 Sept. 2016.

[17] NASA Science Mission Directorate. "Infrared Waves." *Mission:Science*. NASA, 2010. Web. 14 Aug. 2016.

the same way any other source of heat does. Also, though uncommon, just like visible light, long-time exposure to very strong infrared light may cause sight damage.[18]

Microwaves

Microwaves consist of electromagnetic radiation with a wavelength between $\lambda = 1mm$ and $\lambda = 1m$, and have many uses, such as telecommunication and heating food. As its name indicates, the microwave oven uses microwaves to heat substances like water and fat in food in a process called dielectric heating.[19] Even though microwave radiation does not have harmful ionising effects, its dielectric heating properties, more powerful than the heat caused by infrared light, can affect living tissue detrimentally – an injury known as microwave burns, which can include sight issues and teste damage, amongst others – depending on the amount of energy the wave possesses and the type of tissue affected. However, these are very rare with exposure to usual household frequencies.[20]

Radio waves

Finally, at the longest wavelength of usually $\lambda = 1m$ or longer, though it can overlap with the microwave spectrum with wavelengths as short as $\lambda = 1mm$, radio waves have been extremely common in modern life since its surge in the 20th century. As its name indicates, it is the radiation used to transmit information around the globe, such as by radio. Furthermore, it is also how television, phone networks and Wi-Fi, are transmitted.[21]

It is very unclear whether radio waves have any detrimental effects. Firstly, they are far from the ionising limit, and secondly, they do not have the heating properties of microwaves or infrared light. Human studies on relation of the use of mobile phones and cancer, which is the most frequent concern, were not able to prove this link. Some other studies, such as one

[18] Judge, Michael. "What Are the Dangers of Infrared?" *EHow*. Demand Media, n.d. Web. 7 Sept. 2016.

[19] NASA Science Mission Directorate. "Microwaves." *Mission:Science*. NASA, 2010. Web. 14 Aug. 2016.

[20] FDA. "Microwave Oven Radiation." *U.S. Food and Drug Administration*. U.S. Department of Health and Human Services, 1 Sept. 2016. Web. 7 Sept. 2016.

[21] FCC. "The Quality That Made Radio Popular." *FCC.gov*. Federal Communications Commission, 21 Nov. 2005. Web. 24 Mar. 2016.

conducted on rats subjected to a very high dose of radio waves, showed a very slight increase in cancer on male subjects, though this has not been extrapolated to humans. Because of this, various healthcare organisations consider radio waves has a possible, though unproven, carcinogenic.[22]

2.2. Wi-Fi and the spread of Wi-Fi issues

Wi-Fi, a licensing trademark that standardises Wireless Local Area Network (WLAN) connections, is one of these types of radio waves, and is generally broadcast at the frequency of $f_1 = 2.4GHz$ and, more recently, $f_2 = 5GHz$ as well.[23] The exact wavelengths of these two types of wireless signal are as follows, where c is the speed of light in its unit of $^{m}/_{S}$.

$$\lambda_1 = \frac{c}{f_1} = \frac{299792458^{m}/_{S}}{2400000000s^{-1}} \approx 0{,}125m \qquad \lambda_5 = \frac{c}{f_5} = \frac{299792458^{m}/_{S}}{5000000000s^{-1}} \approx 0{,}059m$$

Radio technologies have made many improvements to communication, but recently, besides the cancer-related concerns, a number of people have started to claim to suffer from "electromagnetic hypersensitivity", which is defined as a negative reaction to radio waves, with symptoms such as insomnia and headaches.[24]

Recently, this issue appears to have become more widespread, with the advent of Wi-Fi and mobile networking waves in our daily lives, to the point of lawsuits on the usage of Wi-Fi in schools appearing and suicides apparently being caused by "Wi-Fi allergy".[25] Not only that but, as explained previously, claims have been made of Wi-Fi radiation slowing the growth of plants or even stopping it altogether. Though no proof of effects on humans has been made, as described in section 2.1, the following experiment might give some insight on this.

[22] ACS. "Cellular Phones." *American Cancer Society*. N.p., 4 Dec. 2014. Web. 7 Sept. 2016.

[23] "List of WLAN Channels." *Wikipedia*. N.p., 30 Aug. 2016. Web. 7 Sept. 2016.

[24] Gorski, David. ""Electromagnetic Hypersensitivity" and "wifi Allergies": Bogus Diagnoses with Tragic Real World Consequences." *Science-Based Medicine*. N.p., 7 Dec. 2015. Web. 24 Mar. 2016.

[25] Gye, Hugo. "Schoolgirl, 15, Found Hanged after 'developing an Allergic Reaction to the WiFi at Her School'" *Daily Mail*. N.p., 30 Nov. 2015. Web. 24 Mar. 2016.

3. Experiment on plant growth

3.1. Design

To study the effects of Wi-Fi on the growth of the spearmint seeds, two sets of four plants (Figure 1) will be planted, one in close proximity to the Wi-Fi router and further away. I will also use a Raspberry Pi minicomputer connected to the access point to make sure it is kept online. Ideally, to effectively monitor the effects of a single condition on a certain process, all other conditions should be exactly the same. Of course, that is not entirely possible in this case, because for the radiation to affect one set and not the other, the two sets of plants should either be in two different locations, or in the same location but at different times.

To minimise the effects of external conditions, such as lighting and weather, while still putting one of the sets outside of the reach of the router, I have selected two windows in different rooms on a fourth floor, separated by approximately twenty metres. In one of the rooms, I will set up the Wi-Fi router to broadcast at $f = 2.4GHz$, and I will put four flowerpots with seeds outside the window (Figure 2). The other four pots will be put outside the window of the other room (Figure 3).

This way, lighting and weather conditions will be practically the same, while the Wi-Fi radiation will only reach one of the sets at full intensity. The intensity of other access points' waves is approximately equal between both point and thus negligible in comparison to those of the experiment. I will water the plants daily with the same amount of water, while keeping track of their progress. After approximately a month of growth, I will switch the Wi-Fi waves to be broadcast at $f = 5GHz$ as well, to study if the frequency of the radiation might affect the growth differently.

I will also make sure that the radiation affecting the second set of plants is in fact much less compared to the first set, by using calculation to compare the wave intensity at the two points.

Figure 1. Preparation of the eight plant pots.

Figure 2. Plant pots near the router.

Figure 3. Plant pots away from the router.

3.2. Intensity comparison

The intensity of the Wi-Fi radiation in this part of the experiment can be calculated, and the difference in intensity that reaches the two sets of plants can be compared, using the formulas $E = h * f$ and $I = \frac{E}{\Delta t * s}$ (where E is energy in Joules J, h is the Planck constant $6.63\, J * s$, f is frequency, Δt is the increase in time and s is the surface area of the spherical wave). From here, I can calculate the wave energy E. Then, taking as sample time $\Delta t = 1s$, I can calculate the wave intensity I_1 that reaches the first set of plants at one metre distance to the router, and the intensity I_2 when the Wi-Fi waves reach the second set of mint plants placed at twenty metres distance. The sphere surface area will be calculated using a sphere with radii $r_1 = 1m$ and $r_2 = 20m$, and the formula $s = 4 * \pi * r^2$ The second value is approximated using a satellite picture, since its measure on the outside of the building without safety measures would be a task too dangerous to carry out. Because of this, and because the preciseness of this value is not of high importance, I will not use uncertainty or error margins, and I will regard this result as a rough approximation.

Since the wave frequency appears in the calculation as a multiplying factor, calculating intensity for both frequencies used is unnecessary to compare the intensities between the two points, as the ratio will be the same.

$$s_1 = 4 * \pi * r_1^2 = 4 * \pi * (1m)^2 = 12.6m^2$$
$$s_2 = 4 * \pi * r_2^2 = 4 * \pi * (20m)^2 = 5024m^2$$
$$E = h * f = 6.63J * s * 2400000000s^{-1} = 1.59 * 10^{10}J$$
$$\begin{cases} I_1 = \frac{E}{\Delta t * s_1} = \frac{1.59 * 10^{10}J}{1s * 3.14m^2} = \frac{1.59 * 10^{10}W}{12.6m^2} = 1.26 * 10^9\, {}^{W}/_{m^2} \\ I_2 = \frac{E}{\Delta t * s_1} = \frac{1.59 * 10^{10}J}{1s * 1256m^2} = \frac{1.59 * 10^{10}W}{5024m^2} = 3.16 * 10^6\, {}^{W}/_{m^2} \end{cases}$$

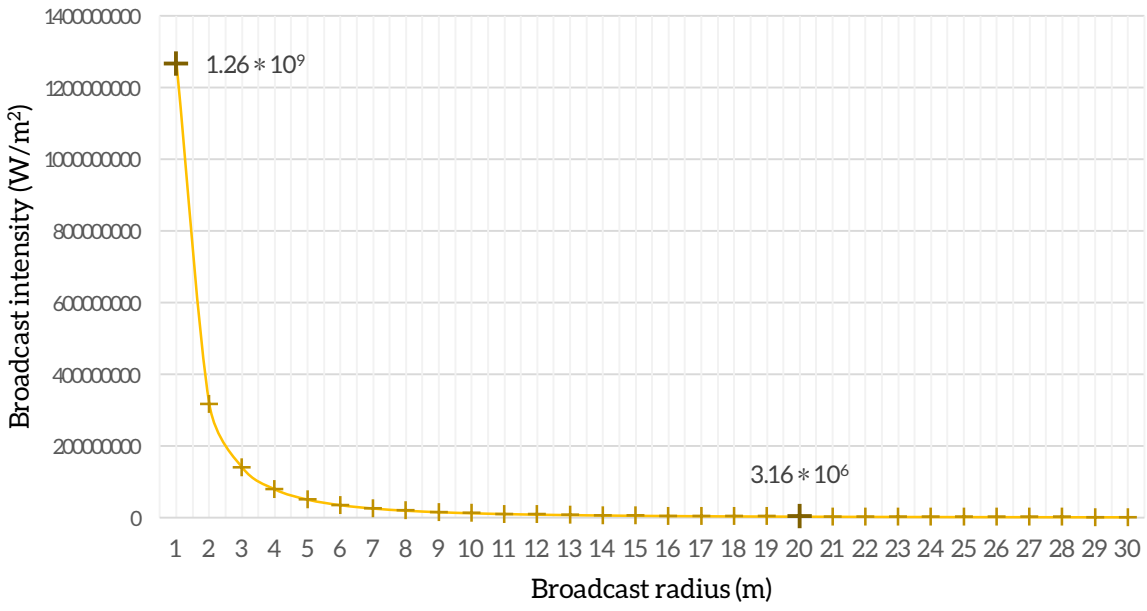
$$\frac{3.16 * 10^6\, {}^{W}/_{m^2}}{1.26 * 10^9\, {}^{W}/_{m^2}} * 100 = 0{,}2\%$$

By dividing I_2 by I_1, it becomes clear that the radiation that affects the second set of plants approximately has only a fifth of a percent of the intensity it has when it reaches the first set and, as such, it becomes clear that, as predicted, the radiation has much lower intensity at the second set of plants, to the point of it almost being non-existent in comparison. This vast decrease in intensity follows an inverse-square law, as can be seen in the graph shown in Figure 4, which compares intensity of Wi-Fi radiation (dependent variable on the Y-axis) in function of the distance from the Wi-Fi access point (independent variable on the X-axis) according to the following formula:

$$I = \frac{E}{\Delta t * s} \rightarrow I = \frac{1.59 * 10^{10}J}{1s * 4 * \pi * r^2} \rightarrow I = \frac{1.59 * 10^{10}W}{4\pi} r^{-2}$$

In accordance with this, trying to establish an internet connection near the second set of plants results in an inability to connect due to poor connectivity.

Figure 4. Broadcast intensity by distance from the access point.



3.3. Results

Wi-Fi at 2.4 GHz

This part of the experiment started at May 2nd 2016, and lasted for slightly more than a month, until June 6th 2016. At that date, the plants looked as shown in Figure 5.

Figure 5. Plants near (top) and away from (bottom) the access point on June 6th.

Wi-Fi at 5 GHz

This part of the experiment took place from June 6th until June 20th. At the final date, the plants looked as shown in Figure 6.

Figure 6. Plants near (top) and away from (bottom) the access point on June 20th.

4. Result analysis

4.1. Growth analysis

Wi-Fi at 2.4 GHz

At this point, the spearmint plants had started to grow steadily in all eight pots, both those under high influence from the Wi-Fi access point as those further away. As can be seen in the pictures in Figure 5, there was even a slight tendency in favour of the first set of plants, where more plants had started to grow than in three of the pots in the second set. However, those that had sprouted reached roughly the same size and height in all eight plant pots. Because of the precision errors in planting seeds and the natural discrepancies in plant growth, there is no clear difference between the two sets.

As such, as this point it seemed that the electromagnetic waves of the Wi-Fi router had had no detrimental effects on the spearmint plants.

Wi-Fi at 5 GHz

At the end of the experiment, as can be seen in the pictures in Figure 6, the spearmint plants had continued to grow steadily in all eight pots. As was the case before starting broadcasting at the wave frequency of 5 GHz, three of the pots in the first set had slightly more plants in them.

The exact maximum height of the plants, from the soil to their tallest point, as measured with a ruler with an uncertainty of $\Delta h = 0.1cm$, was as follows: for those next to the router, $h_1 = (10.8 \pm 0.1)cm$, $h_2 = (10.6 \pm 0.1)cm$, $h_3 = (8.4 \pm 0.1)cm$ and $h_4 = (18.5 \pm 0.1)cm$; for those at twenty metres, $h_5 = (17.6 \pm 0.1)cm$, $h_6 = (10.6 \pm 0.1)cm$, $h_7 = (9.9 \pm 0.1)cm$ cm and $h_8 = (9.5 \pm 0.1)cm$. These values can be compared in the graph shown in Figure 7, which has the various plants, grouped by set and ordered by height, on the x-axis and their respective heights on the y-axis.

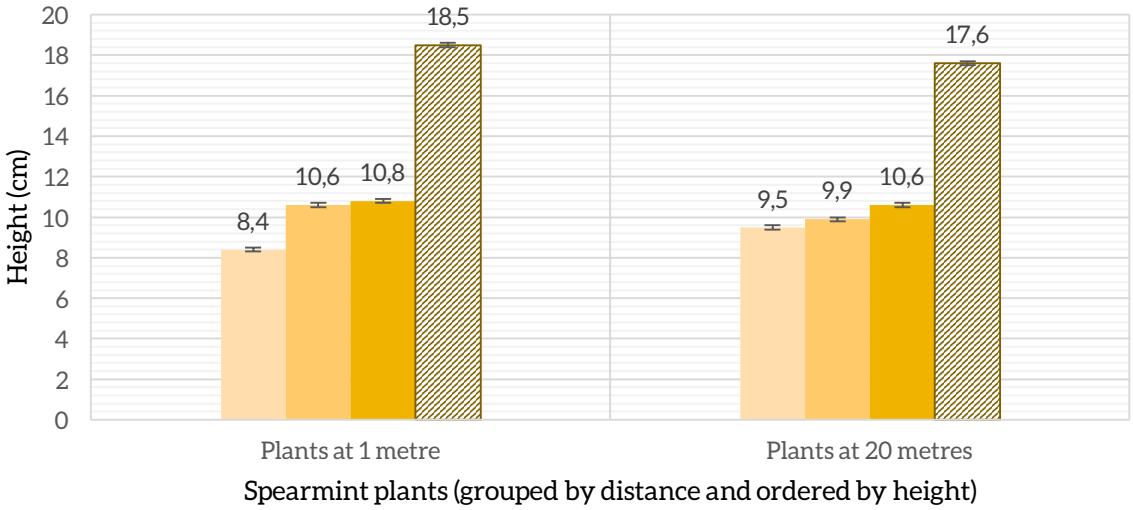
As can be seen in Figure 7, both sets have a value that is much higher than the others ($h_4 = (18.5 \pm 0.1)cm$ and $h_5 = (17.6 \pm 0.1)cm$, marked with a diagonal pattern) and, as such, I will consider this high growth as coincidental, and their values as outliers. The average heights of both sets - h_a for the set at 1 metre and h_b for the one at 20 metres – without these outliers, and calculating their respective uncertainties from the difference between the average and the most separated value, are as follows:

$$h_a = \frac{h_1 + h_2 + h_3}{3} = \frac{10.8cm + 10.6cm + 8.4cm}{3} = 9.9cm$$
$$\Delta h_a = |h_a - h_3| = |9.9cm - 8.4cm| = 1.5cm$$
$$h_b = \frac{h_6 + h_7 + h_8}{3} = \frac{10.6cm + 9.9cm + 9.5cm}{3} = 10.0cm$$
$$\Delta h_b = |h_b - h_6| = |10.0cm - 10.6cm| = 0.6cm$$

The average heights are $h_a = (9.9 \pm 1.5)cm$ for the spearmint plants at 1 metre, and $h_b = (10.0 \pm 0.6)cm$ for those at 20 metres. These values are extremely close and, when taking into account the uncertainty margins, they are practically the same. Furthermore, after the initial difference in the amount of plants, no actual growth disparities had appeared.

Because of this it seems that, just as with the 2.4 GHz radiation, the 5 GHz Wi-Fi waves have no detrimental effects on the growth of plants.

Figure 7. Plant height at the end of the experiment



4.2. Interpretation

After having carried out the experiment with both radiation frequencies, the fact that in neither case the growth of the spearmint plants differed significantly, and in no case favoured the idea of the radiation affecting growth negatively, seems to support the more accepted point of view – that is, the claim that this kind of electromagnetic waves have no effect on life forms whatsoever.

This would mean that the studies claiming that plants wouldn't grow around a Wi-Fi router, such as those cited in section 1, were mistaken or misinformed.

Weaknesses and uncertainties

Even so, this experiment could as well have certain weaknesses. Even though alimentation and temperature were accounted for, there might be a chance other, more uncontrollable factors affected the spearmint plants.

It is possible that, due to the slope of the mountain behind of which the sun rises, one set of plants could have gotten slightly more sunlight every day. Another possibility is that other types of electromagnetic radiation, that could technically have the same detrimental effects as Wi-Fi waves might have, were more active around the second set of plants. These factors, though unlikely, could have affected the plants in such a way that they nullified whatever effects the Wi-Fi router might have had.

While these weaknesses add a certain degree of uncertainty to the result of the experiment, they are only small possibilities, and they do not directly discard it.

5. Conclusions

The following initial conclusions can be obtained for the two goals outlined in section 1:

1. The research written about in section 2 showed that it is uncertain whether radio waves, and in particular Wi-Fi radiation, have any detrimental effects on living tissue, be it plants, animals or humans.
2. The experiment performed, detailed in sections 3 and 4, did not prove much more conclusive. Even if it seems that, due to the fact that both spearmint plants influenced by Wi-Fi and plants that were not, this radiation had no effect at all on their growth, this does not mean there wouldn't have been any adverse effects in the long run, such as a shortened lifespan.

However, the result that the growth isn't affected either conflicts with that of a particular study conducted in a Denmark school, cited in section 1. This could be because the way in which the Danish experiment was conducted could very possibly have been flawed. For instance, there might have been a mistake in taking various variables into account, or that the experiment design itself was flawed, which would be the case if, for example, the heat generated by the router and computers used around the plants affected their growth or even simply vaporised part of their water supply.

Another thing to point out is that, while my experiment in no way gives conclusive evidence on this, if the growth of plants is not affected by Wi-Fi waves, it rules out that animals might be affected in a similar way. For example, the idea of Wi-Fi affecting animal or human cells at their most basic structure, which already seems highly improbable due to the fact that radio waves do not have ionising capabilities, is improbable because they share the basic structure of cells with plants.

In short, while this experiment seems to make the idea of Wi-Fi and radio waves as a whole being harmful a bit less probable, nothing can be said for sure – a point of view shared, as explained in section 2, by many scientists and healthcare organisations such as the WHO. The harmfulness, even if small, of radio waves remains an area that needs to be explored and investigated in order for us to obtain a better understanding of it.

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