# Study of electromagnetic field effects on plants evolution using MATLAB analysis

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***Abstract*— This paper is intended to be a different study on the effects of an electromagnetic field on the evolution of plants. The idea behind this work came during the pandemic when disinfection was performed with the help of ultraviolet lamps. The first question concerned the negative effects of ultraviolet radiation on living organisms in rooms subjected to sanitization using this method. As a result, the natural question was what the influence of the radiofrequency electromagnetic field on the same organisms was. All these questions and studies had in mind the environment in which the authors of the paper, a military environment in which electromagnetic radiation is constantly present. To answer these questions, experiments were carried out in which wheat, bean, or ivy plants were involved. Plants' evolution was monitored for several days. Measurements were made of the dimensions of the plants and pictures were taken at different stages of plant development. This paper does not aim to provide other evidence in support of the claims that an electromagnetic field negatively influences living organisms, but only analyses and processes with the help of MATLAB the results obtained from the experiments carried out. However, pictures and measurements taken during the experiments confirmed the insufficient development of living organisms under the action of the electromagnetic field.**

***Keywords*— *Computer simulation, Electromagnetic field, Histogram, Image processing, MATLAB analysis, Radiofrequency, RGB channels, Ultraviolet radiation.***

## I. INTRODUCTION

The study of the biological effects of the electromagnetic field represented and still represents a challenge. The principle of interaction between complex biological processes, physics, and the production of electromagnetic fields is the phenomenon to be studied, [1]. This study is difficult to accomplish because of the complexity, multiple levels of organization of living organisms, and wide range of electrical and magnetic properties of tissues. The process of understanding the possible health hazards caused by the electromagnetic field is still ongoing. Two notions must be differentiated between them: biological effects and health implications. [2], [3], a biological effect represents any physiological response to a stimulus, in the case of the present study exposure to an electromagnetic field. Some biological effects may have no impact on health, some may have beneficial outcomes, while others may lead to visible pathological signs and symptoms. Exposure to electromagnetic fields increases the likelihood of adverse health effects. There are cases in which the effects of the electromagnetic field can be beneficial; applying them with a specific orientation and intensity to endogenous physiological fields in living organisms. Examples of beneficial effects of the electromagnetic field on living organisms are multiple: development/healing of wounds/bones, and skin regeneration, [4]. It is important to consider the negative effects of electromagnetic waves on health and the possibility of their use in biomedical applications. Health implications are the result of external and environmental factors, or biological effects that accumulate over time. For an electromagnetic field to cause negative effects on a living organism, the field must interact with a basic component of matter, an atom, or a molecule (an example would be the body's biological reactions to oxidative stress). The cellular effects of this interaction can cause biological changes that could lead to "health" problems. Living organisms are complex systems that have evolved over the years, interacting with, and adapting to the conditions of the electromagnetic environment to regulate different cellular systems. Electromagnetic fields are ubiquitous in our society, and they appear in the use of electricity, electronic surveillance systems, and various types of wireless communications, [5].

Currently, concerns are directed at the possibility that long-term exposure to weaker fields may have harmful effects on living organisms. The effects of the radio spectrum, infrared radiation, visible spectrum, ultraviolet radiation, and X-rays and Gamma rays on living organisms are considered.

This paper presents an analysis of the development, growth, and manifestation of some types of plants subjected to electromagnetic fields at different frequencies. [6], the frequencies used were in the ranges corresponding to radio and ultraviolet waves.

## II. PERFORMANCE OF THE EXPERIMENTS TO VISUALIZE THE EFFECTS OF RADIATION ON PLANTS

For the experiment, three types of plants were used: wheat, beans, and ivy, with two types of radiation, radio waves and

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ultraviolet (UV) radiation, in different combinations. A SkyRadar system and a UV lamp were used to obtain radiation. Equal lighting, irrigation, and heat conditions were created for all types of experiments, removing any disturbing signals (phone, laptop, wireless headphones, speaker) that could influence the normal growth of the plants.

The first experiment aimed to visualize the effects of radiofrequency radiation on wheat and bean plants. The second experiment followed the evolution of wheat and ivy plants under the action of ultraviolet rays. For this, four beans placed in two containers of the same type were used: 15 grains of wheat were placed in four containers of the same type and two ivy seedlings were placed in the same growth conditions without radiation, [7].

On the first day of the experiments, the first data on plants, color, and size were collected. Table I shows the measured data.

TABLE I. PLANT LENGTHS ON THE FIRST DAY OF THE EXPERIMENT IN EACH OF THE FOUR ENVIRONMENTS

| Plants / Length in diferrent environment | WHEAT | BEAN | IVY |
|---|---|---|---|
| Radio wave environment | 30 cm | 4 cm | - |
| Radio wave-free environment | 35 cm | 1 cm | - |
| Ultraviolet radiation environment | 34 cm | 1 cm | 10 cm |
| Ultraviolet free environment | 34 cm | 1 cm | 9 cm |

The continuation of the experiments consisted of exposing the plants to electromagnetic radiation. Wheat and beans were placed under the influence of radio waves produced by the SkyRadar system with a frequency of 24.04 GHz, with a bandwidth of 300 MHz, and a power of 79 mW. The wheat, beans, and ivy were placed under the influence of ultraviolet radiation produced by a lamp with a wavelength of 185 nm and power of 36 W.

It should be noted that the comparisons made were between plants subjected to the same type of radiation, so the power and frequency differences between the two radiation systems used in the experiment were not important.

From Table I, it can be observed from the first day that the plants, although initially developed in the same environment, had different developments, a fact that is visible in the continuation of the experiment (Table II).

TABEL II. GROWTH RATE OF PLANTS IRRADIATED WITH RADIO WAVES

| DAY / PLANTS | DAY 1 | DAY 7 |
|---|---|---|
| Wheat grown in radio wave environment | 30 cm | 40 cm |
| Wheat grown in the free radio environment | 35 cm | 42 cm |
| Beans grown in the radio wave environment | 4 cm | 12 cm |
| Beans grown in the radio free environment | 1 cm | 12 cm |

The first differences noted were in growth, values fully listed in Table II, but it can be seen that six days after the start of the experiment on the plants, no major changes were noted in their development. The experiment continued until day 28. In an intermediate stage, day 21, the wheat and bean plants looked like in Fig. 1.



Fig. 1 Wheat and bean plants on day 21: under the action of radio waves (left) and in an environment without the action of radio waves (right)

TABLE III. THE GROWTH OF PLANTS IRRADIATED WITH RADIO WAVES UNTIL DAY 28

| DAY / PLANTS | DAY 1 | DAY 7 | DAY 21 | DAY 28 |
|---|---|---|---|---|
| Wheat grown in radio wave environment | 30 cm | 40 cm | 46 cm | 46 cm |
| Wheat grown in the free radio environment | 35 cm | 42 cm | 54 cm | 61 cm |
| Beans grown in the radio wave environment | 4 cm | 12 cm | 29 cm | 29 cm |
| Beans grown in the radio free environment | 1 cm | 12 cm | 41 cm | 50 cm |

A clear differentiation in growth was observed which continued until day 28 when the plants subjected to the action of radio waves died.

Table III shows the measurements on day 28 for the experiment with the radio-wave radiation.

The second experiment dedicated to studying the effects of UV radiation also demonstrated a negative effect on plants.

Table IV shows the measurements made for plants subjected to 15 min/day for 21 days. How wheat plants look like it can see in Fig. 2: in an environment with UV radiation and in an environment without UV radiation. The plants shown in Fig. 2 were subjected to the measurements after which the values from Table IV were obtained and were analyzed by MATLAB in the following stages.

TABLE IV. THE GROWTH OF PLANTS SUBJECTED TO UV RADIATION

| DAY / PLANTS | DAY 1 | DAY 7 | DAY 21 |
|---|---|---|---|
| **Wheat grown in ultraviolet radiation environment** | 34 cm | 37 cm | 37 cm (the plant withered) |
| **Wheat grown in the ultraviolet radiation free environment** | 34 cm | 44 cm | 53 cm |
| **Beans grown in ultraviolet radiation environment** | 1 cm | 13 cm | 13 cm (the plant withered) |
| **Beans grown in the ultraviolet radiation free environment** | 1 cm | 17 cm | 25 cm |



Fig. 2 Wheat plants on day 21: under the action of UV radiation (left) and in an environment without the action of UV radiation (right)

Ivy was also subjected to UV radiation and the effect of this radiation is shown in Fig. 3.

## III. MATLAB ANALYSIS OF PLANT EVOLUTION

Although the images of the plants are quite suggestive of the action of the two types of radiation on the plants, this paper proposes a study in MATLAB to highlight the effects of these radiations. For this, the growth rate was analyzed for plants subjected to radio frequency, ivy plants, and wheat plants subjected to UV radiation, [8].



Fig. 3 Ivy plants on day 21: under the action of UV radiation (left) and in an environment without the action of UV radiation (right)

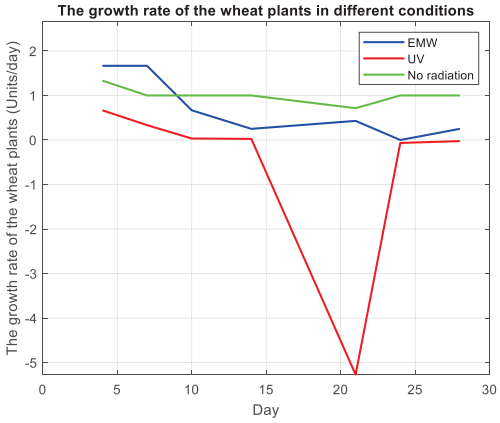



Fig. 4 The growth rate of wheat

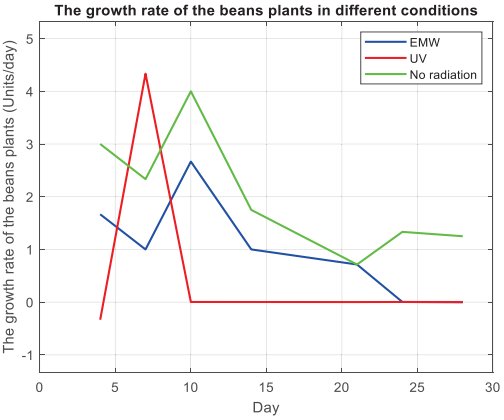



Fig. 5 The growth rate of beans

The first analysis carried out in MATLAB focused on the influence of radiation on plant growth. Considering that the same type of plant grows differently and under normal conditions, it is difficult to appreciate plant growth in absolute value units. The growth rate is defined as follows:

$$growth\ rate = \frac{difference\ in\ the\ height\ of\ plant}{difference\ between\ the\ number\ of\ days}$$

In Fig. 4 the evolution of the wheat plants in the three growth environments is shown. In Fig. 5 the evolution of bean plants in the same three environments, with UV, RF, and no radiation is presented.

The growth rate in the environment without radiation (green graph) was the most constant and the lowest growth rate was observed in plants subjected to ultraviolet radiation. Moreover, it can be observed that in an environment with UV radiation (red), the growth rate is zero or almost zero starting on day 21 for wheat plants and on day 10 for bean plants (red graph).

The second type of analysis in MATLAB was performed for visualization to determine the effect of UV radiation on plant health. Ivy and wheat plants were selected for analysis. The analysis was performed in the following stages:

1. Segmentation of images in Fig. 6 is necessary to separate and highlight the green or dry leaves of plants.

2. The RGB colors (red, green, and blue) were extracted, and the images were analyzed by calculating the average color values.
3. Obtaining and displaying the histograms for the intensities of the respective green color and the combination of colors corresponding to the dry leaves in the two cases (environment with UV radiation and environment without radiation).

The segmentation corresponding to the ivy plant was achieved by converting RGB space into HSV space (Hue, Saturation, Value), by extracting the channel that represents the tone of a color (HUE). For the detection of green, yellow, and brown colors, two thresholds (combinations of RGB) were imposed: one for the green color and the other for combinations of green, yellow, and brown.

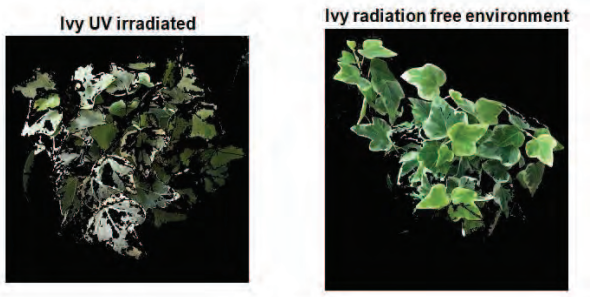



Fig. 6 Image segmentation for the UV-irradiated ivy plant (left) and for the plant in an environment without radiation (right)

To understand the histograms, the average values of the RGB channels were extracted and the differences between the values obtained for the irradiated plant and the one developed in an environment without radiation were calculated (Table V).

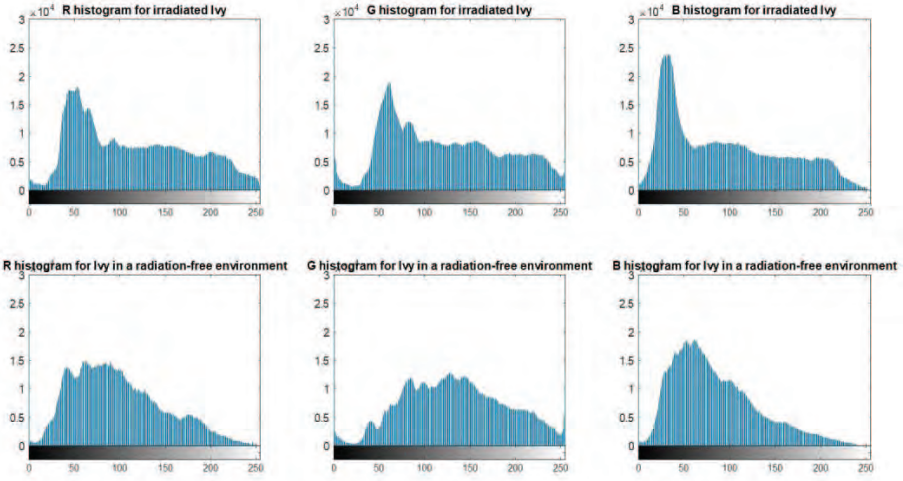



Fig. 7 Histogram of the RGB channels for the analysis of the UV-irradiated ivy plant (up) and in an environment without radiation (down)

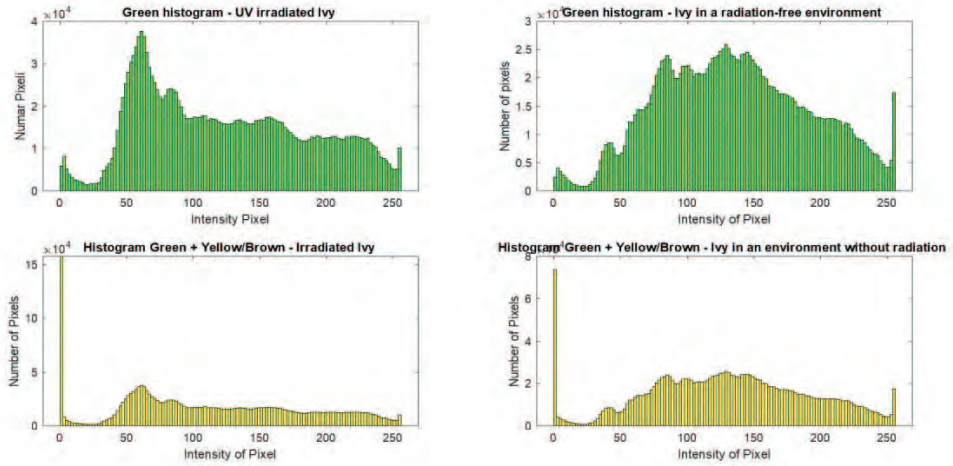



Fig. 8 Histogram of the green color and the combinations of green, yellow, and brown for the analysis of the UV-irradiated ivy plant (left) and in an environment without radiation (right).

TABLE V. AVERAGE RGB VALUES OF THE HISTOGRAMS IN FIG.7. AND FIG. 8.

| Image | Mean R | Mean G | Mean B | Combined |
|---|---|---|---|---|
| UV irradiated IVY | 114.52 | 123.21 | 94.97 | 0.08 |
| IVY in a radiation-free environment | 99.19 | 134.98 | 84.88 | 0.07 |
| | | | | |
| Differences | Diff mean R | Diff mean G | Diff mean B | |
| | 15.33 | -11.77 | 10.09 | |

The interpretation of the data from the tables emphasizes what can be visualized in all images that presented ivy in different stages of evolution.

Diff mean R: (mean difference for the red channel) was 15.33, indicating that the mean intensity of the red channel increased in the case of the plant exposed to UV radiation compared to the plant in the environment without radiation. An increase in red could suggest that there is an increase in red pigments, such as anthocyanin, which can occur in response to UV stress.

Diff mean G: (mean difference for the green channel) was -11.77, which means that the mean intensity of the green channel decreased in plants exposed to UV. The green pigment is mostly attributed to chlorophyll, therefore a decrease in the green channel can indicate a breakdown of chlorophyll or a decrease in its concentration, which is often a sign of stress or damage in plants.

Diff mean B: (mean difference for the blue channel) is 10.09, indicating an increase in blueness. This could reflect changes in other pigments or be correlated with changes in anthocyanins, although this depends on the specific context of the plants and their growing conditions.

A second comparative study was carried out based on an experiment that followed the behavior of the wheat plant under the action of two types of ultraviolet radiation and radiofrequency, and its development in an environment without radiation. After the experiment, images containing the information were taken and processed with MATLAB, and the effects on the plant were analyzed. The histograms provided by the program for processing the three images are shown in Fig. 9.

The figure shows the histogram for the decomposition of the respective RGB channels for the green colors and their combination with yellow and brown images as a whole.

The algorithm used to obtain this information was similar to that applied to the study of ivy behavior. The first stage involved separating the color information for the three cases in which wheat was found. For this separation, as a result of the observations on the images of the plant, a threshold was imposed to allow the differentiation of shades of green and its combinations with those of yellow and brown, as exemplified below.

*% Threshold to detect green colors:*

green_mask3 = (hue3_channel > 0.2) & (hue3_channel < 0.4);

green_mask4 = (hue4_channel > 0.2) & (hue4_channel < 0.4);

green_mask5 = (hue5_channel > 0.2) & (hue5_channel < 0.4);

*% Threshold to detect dry leaf colors (eg brown/yellow):*

dry_mask3 = (hue3_channel > 0.13) & (hue3_channel < 0.16);

dry_mask4 = (hue4_channel > 0.13) & (hue4_channel < 0.16);

dry_mask5 = (hue5_channel > 0.13) & (hue5_channel < 0.16).

From Fig. 9. it was observed that the wheat samples irradiated with UV and RF showed a distribution of intensities for green which was different from that of the sample without radiation, the histograms of the red and green channels of the UV and RF irradiated wheat are shifted to the left compared to those of the non-irradiated wheat. It is observed that on the red and green channels, there are high peaks in the same intensity region and the blue is more flattened compared to the case of the non-irradiated plant. Comparing the green histogram from the UV and RF irradiated samples to the non-irradiated samples, it can be seen that there are changes in the frequency of certain green intensities, indicating a change in the pigmentation or reflectance of wheat following exposure to these types of radiation. This is consistent with the observations shown in Fig. 10, the pixel intensity distribution for the green color and a combination of green/yellow/brown in wheat images under the three development conditions. If wheat shows a preponderance of green under normal conditions, a shift to yellow/brown in the combined histogram suggests that the wheat has been affected in a way that alters its health or vitality, such as drying or various diseases. Fig. 10. shows large variations between the green and combined histograms in irradiated versus control (no radiation) samples. High peaks in the green histogram of unirradiated wheat suggest a greater presence of chlorophyll or better overall plant health, reflecting a high concentration of pixels with high light intensity, which is characteristic of healthy vegetation. The green histogram of irradiated wheat shows lower peaks and is slightly shifted to lower intensity values, indicating a loss of green pigments or a negative effect of radiation on plant health.

The variations observed in the histograms of irradiated wheat versus unirradiated wheat show that radiation can have noticeable effects on plant appearance by affecting pigmentation or other physical characteristics.

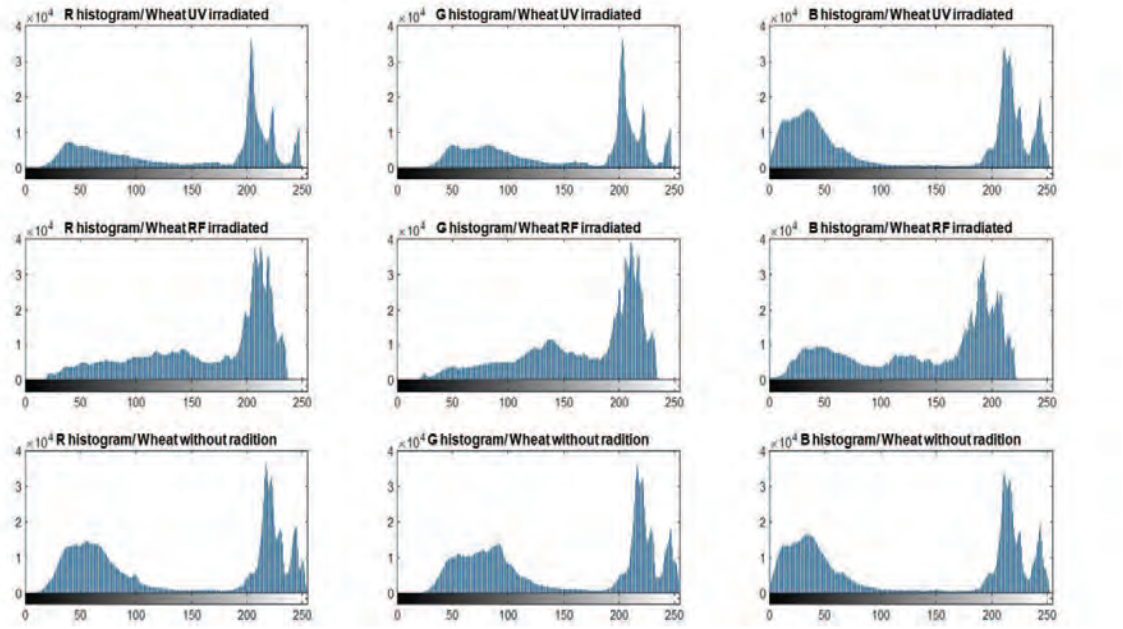



Fig. 9 The histograms on the RGB channels for the analysis of the wheat plant irradiated with UV (left), RF (middle), and in an environment without radiation (right).

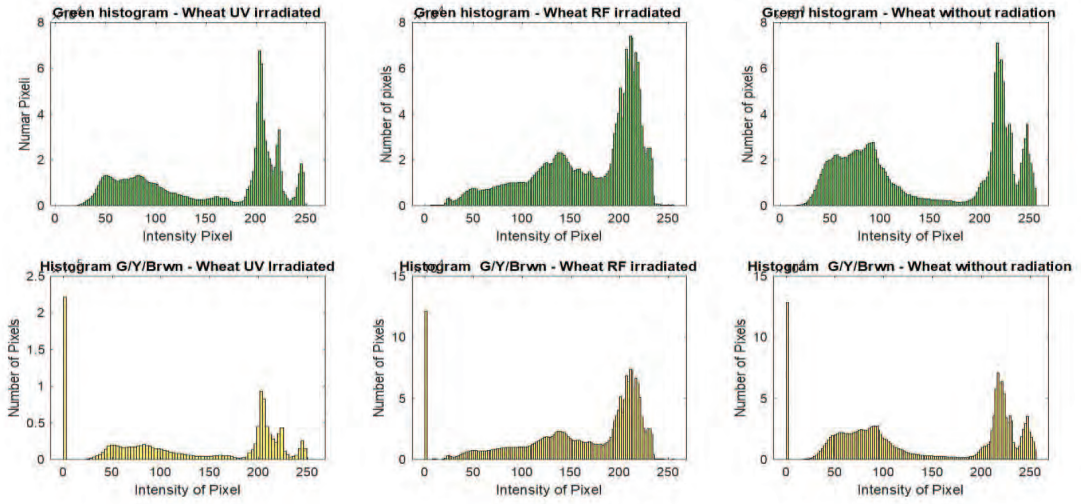



Fig. 10 Histogram of the green color and the combinations of green, yellow, and brown for the analysis of the wheat plant irradiated with UV (left), RF (middle), and in an environment without radiation (right).

A comparison between the effects of the two types of radiation is presented in Table VI.

A higher intensity of the green color is observed for the RF-irradiated wheat compared to the UV-irradiated one, with a negative difference between the mean values of the intensities for the UV-irradiated and the RF-irradiated wheat. Specifically, the average intensities for the RF image were higher than those for the UV image for all three color channels (R, G, and B). This suggests that RF-irradiated wheat exhibits higher reflectance, that is, it is brighter in each of the RGB channels compared to UV-irradiated wheat.

TABLE VI. AVERAGE RGB VALUES FOR THE TWO TYPES OF UV, AND RF IRRADIATION OF WHEAT

| Image | Mean R | Mean G | Mean B | Combine values |
|---|---|---|---|---|
| Wheat UV irradiated | 147.74 | 151.79 | 130.74 | 0.18 |
| Wheat RF irradiated | 163.99 | 166.74 | 138.99 | 0.23 |
| | | | | |
| Differences | Diff mean R | Diff mean G | Diff mean B | |
| | -16.25 | -14.94 | -8.24 | |

## IV. DISCUSSION SECTION

The keywords Computer simulation, Electromagnetic field, Histogram, Image processing, MATLAB analysis, Radiofrequency, RGB channels, and Ultraviolet radiation, are the main objectives discussed in the paper. Through computer simulation, the use of MATLAB for image processing was aimed to interpret the measurements obtained from the experiments. The action of radio frequency and ultraviolet radiation, the particular values of the frequencies under which the electromagnetic field can be found, was physically realized and interpreted with the help of MATLAB.

The histograms presented in Fig. 7, Fig. 8, Fig. 9, and Fig. 10, their development according to the three RGB channels, and their interpretation by the physical effects visible on plants subjected to radiation highlight the action of the electromagnetic field on some living organisms. Most studies present mathematical modeling of electromagnetic field effects, [9], [10].

The presented study proposes another approach to studying the effects of the electromagnetic field, the experimental one, following which practical measurements and visual observations can be made. The limitation of this type of approach is from the perspective of the impossibility of interpreting the results obtained in MATLAB. If for the calculation of the plant growth rate under the action of the electromagnetic field the results are clear (Fig. 4 and Fig. 5.), it cannot be said the same about the interpretation of the MATLAB results. For a correct interpretation, the latter must be correlated with images of plants at different growth stages.

To obtain very precise results, the studies should correlate and compare the effects following exposure for the same duration, at the same type of frequency, with the same power of the radiation sources, and above all in the same environmental conditions.

Considering all these and the fact that never two plants grow the same even if they are subjected to the same environmental conditions, we discover another limitation of the experiments regarding the effects of the electromagnetic field on living organisms.

The experimental results and their interpretation try to answer the question "The effects of the electromagnetic field - myth or truth?" although he cannot give a clear verdict.

## V. CONCLUSION

The experiments carried out and their analysis with the help of MATLAB show that for more pronounced visibility of the effects of radiofrequency radiation, a longer time is required compared to the case of UV radiation. However, it was observed that as the experiment progressed from one period to another (7 days, 14 days, etc.), the chlorophyll disappeared (the leaves turned yellow or brown), the growth rate dropped to zero, and the plants died.

In conclusion, damage to plant development under the action of an electromagnetic field occurs regardless of the type of frequency at which the electromagnetic radiation appears.

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