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Effects of RF/MW Exposure from Mobile-phone Base-Stations on the Growth of Green Mint Plant using *Chl* a Fluorescence Emission

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Abstract

We report on the effects of RF/MW on plants. Green Mint plant exposed to different levels of radiation (from **0.5** to **10.5** μW/cm^2) for this purpose. A USB2000 spectrophotometer was used to record fluorescence signals from intact leaves.
Spectroscopic data (**P.I.R** and **A.R**) together with vegetative data (leaf dimensions and weight), revealed stressing effects on plant due to RF/MW in all groups except the control which was free of exposure.

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1. Introduction

The drastic development in the field of telecommunications and wireless technology resulted in a wide use of devices based on radiofrequency (RF) and microwave (MW) electromagnetic fields. This in consequence lead to wide spread of transceivers in many countries, where they can be found everywhere in different forms and designs. This on the other hand raised questions on the possible hazards from being exposed to radiation from sources of wireless communications in general, the thing which urged researchers to put effort on the answer of this question [1,2]. Intensive study of the effects of low frequency EM waves on living organisms, is highly needed for this purpose.
Our objective was to study the possible effects of RF/MW radiation emitted from base-stations, on the growth of plants. Induced fluorescence spectroscopy has proven to be a powerful technique in the studies of the physiological changes of plants [3, 4,5]. Characteristic of intact leaves of plants are two main fluorescence emission spectra centered around 685 nm and 735 nm. These two spectra are known to refer to two protein complexes in the plant photosynthetic system called photosystems PSII and PSI respectively. Fluorescence signal of intact leaf is dependent on the excitation source, and its intensity may vary due to the geometry of experiment, but the ratio between the two peaks intensities will not [6]. Therefore the peak intensity ratio (P.I.R) was used in previous studies as a measuring parameter for the possible physiological changes due to development in the plant system [7], or due to stresses from different sources [8]. Spectroscopic parameters used to be measured include in addition to the fluorescence spectra, peak wavelengths, peak intensity, area under the curve, and the peak intensity ratio (P.I.R) and area ratio (A.R) of the main fluorescence emission spectra. Vegetative parameters on the other hand, add informative data to the spectroscopic ones, which at the end give good information about the stress of RF/MW on plant as living organism.

2. Materials and Methods

2.1. Materials

2.1.1. Plants

Green Mint plant sowed in a soil composed of a mixture of clay and sand, during the summer of 2012 (March and April), at Khartoum city in Sudan, where the temperature ranged between 20 to 46 ^{o}C. It was grown under sunlight. Plant divided equally into five groups, each group grown in a separate pot of the same type and dimensions, and all groups were irrigated in the same manner and frequency.

2.1.2. RF/MW Radiation source/detector

Mobile-phone base-station belongs to Zain Company in Sudan, was used as a source of RF/MW radiation emission. The antenna which was located at the roof of a building, operates in frequency range between 800 and 1000 MHz.
A power density meter of the type Narda EMR300, from USA with certified calibration, was used to measure the power density (in mW/cm^2) around the tower.

2.1.3. Spectrometry

A compact USB2000 spectrophotometer from ocean optic Company (USA) was used for fluorescence signal collection. The spectrometer scans wavelengths from 350 to 1100 nm with a resolution of 1.34 nm FWHM. Light emitting diode LED with 450 nm wavelength and 60 μW output was used as excitation source for the intact leaf of plants. The spectrometer is coupled from one side with a fiber optics cable for signal collection, and connected from

the other side to a laptop computer through a USB cable for data transfer.

2.2. Methods

Pots containing plants under test were located at distances of 10, 20, 30, and 50m from the base of the base-station. These groups were subject to radiation exposure of 0.5, 5.3, 8.2, and 10.5 $\mu W/cm^2$, respectively. The fifth group was set free of radiation exposure to be used as a control group. Excitation signal from the blue LED incident on the intact leaf through a fiber optics cable, while the fluorescence emission signal was collected through the second fiber optics cable connected to the spectrometer. Signals were recorded after sunset, in a frequency of two days and thin averaged per week. Fluorescence parameters were calculated from the Gaussian fit of the spectra. Data manipulated using Microsoft computer program ORIGIN 8.0.

3. Results and analysis

Results obtained during this work are summarized in tables and figures below. Details of data were shown for the control only (table 1), while results of other samples are tabulated all together. Vegetative data are shown in figure (4), and table 3 in this session.

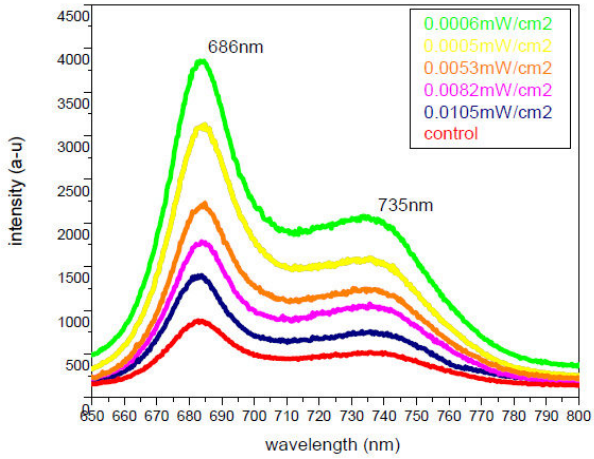

Figure 1: Steady-state fluorescence spectra of all groups of Green Mint, recorded at the same time after excitation by blue LED.

Table 1. Fluorescence parameters calculated from spectra of control group of Green Mint after Gaussian fit.

Wn	λ_1 (nm)	λ_2 (nm)	I_{F1}(a.u.)	I_{F2}(a.u.)	$A_1(cm^2)$	$A_2(cm^2)$
W2	683.6	736.5	1805.1	1087.1	52041.0	63124.0
W3	684.4	736.4	2181.3	1363.5	44230.8	49709.0
W4	684.8	736.9	0946.0	0603.1	29727.5	39035.0

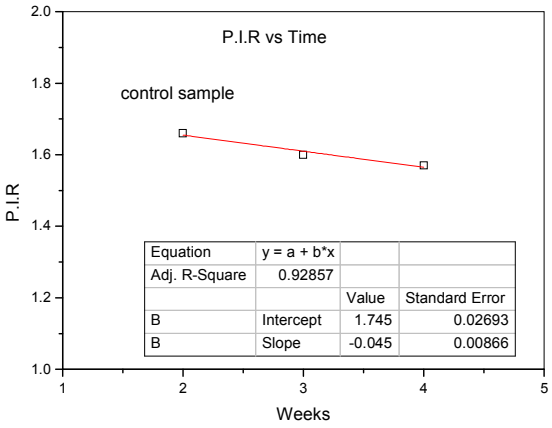

Figure 2. P.I.R vs time for the control group of Green mint. Linear fitting of data shows straight line with negative slope.

Table 2: P.I.R of control/exposed groups of Green Mint.

Wn	control	0.5	5.3	8.2	10.5
W2	1.66	1.60	1.59	1.48	1.55
W3	1.60	1.69	1.89	1.93	1.92
W4	1.57	1.88	1.86	1.83	1.80

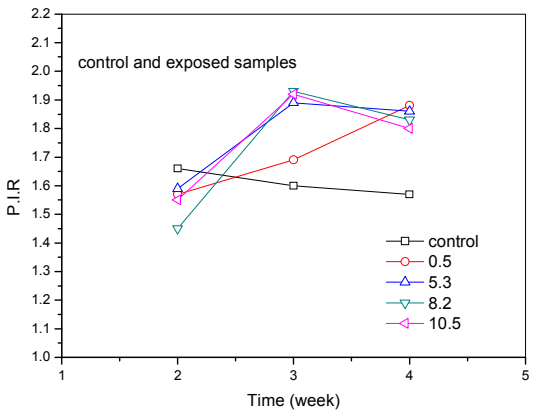

Figure 3. P.I.R vs time for control and exposed groups of Green Mint. Square-black data represents the control group.

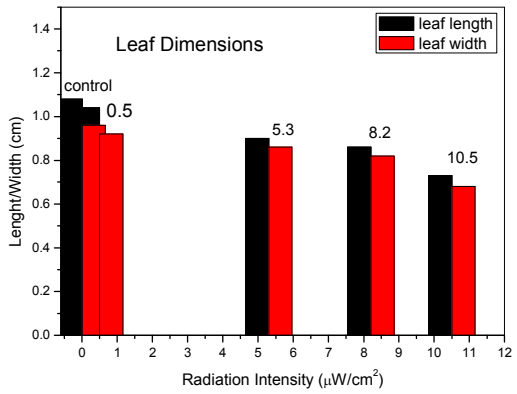

Figure 4. Leaf dimensions for all tested groups of Green Mint (i.e. length (black bars) and width (red bars)).

Table 3. Fresh and dry weights of the tested Green Mint groups. Last column measures ratio of dry to fresh leaf weight.

Exposure level ($\mu W/cm^2$)	Fresh weight (g)	Dry weight (g)	R
0.0	1.08	0.96	0.888
0.5	1.04	0.92	0.885
5.3	0.90	0.86	0.956
8.2	0.86	0.82	0.953
10.5	0.73	0.68	0.931

4. Discussion

Results shown in figure (1) represent fluorescence signals of Green Mint obtained from all groups recorded at one day of measurements. The main observation here is the appearance of the two peaks referring to PSII and PSI photosystems in all spectra, but with different levels of fluorescence intensity. The control group showed the minimum level of fluorescence intensity relative to the exposed groups. Due to [A. S. Ndao], lower fluorescence signal indicates higher amount of chlorophyll content in normal green and dark green plants.

From table (1) the peak wavelengths of Green Mint are centered around 684 nm and 736 nm with slight blue and red shifts. Data fitting of this group as presented in figure 2, shows that P.I.R for Green Mint decreases linearly during the time of growth. This suggests regular increase in the amount of chlorophyll content with time in the normal growing Green Mint. When taken in comparison with the exposed groups as in figure 3, data shows reverse pattern of the P.I.R relative to that of the control group shown in figure 2. Indication of chlorophyll content reduction is observable due to the increase in the P.I.R during the same period of time.

Vegetative data which were measured at the end of the experiment, also indicated physiological differences between the control group and all exposed groups. In figure (4) the leaf dimensions are presented. Black bars for the length and the red bars for the width of the leaf. Control group showed the highest leaf length and width followed by the group placed at the furthest distance (50m) which was subject to the minimum exposure level in our experiment (i.e. subjected to radiation exposure level of 0.5 $\mu W/cm^2$). The group with the smallest leaf dimensions was that exposed to the highest radiation exposure level in the experiment (i.e. 10.5 $\mu W/cm^2$). Dimensions appeared to shrink according to the levels of radiation exposure.

Fresh and dry weights were also measured and tabulated as in table (3). It is clear from this table that for both fresh and dry conditions, the control group (normal growing plant) recorded the highest values of weight. Fresh and dry weights showed to decrease gradually with the gradual increase of the radiation exposure intensity. The third column in the table shows the ratio of dry to fresh weight for the tested groups. This indicates that radiation exposure affects the freshness of Green Mint negatively. Vegetative data showing indications of chlorophyll content reduction in the exposed plant samples, were consistent with the spectroscopic data. RF/MW radiation seems to cause stresses on the plant under study.

The levels of exposure used in our experiment were far below the thermal effect level of the RF/MW radiation on biological tissues. This means that other interactions (electric, magnetic, electromagnetic) are probable.

5. Conclusions

RF/MW radiation even though of small levels of exposure are cable of causing stresses on the studied plant, and most probably on other types of plants. Types of stressing interactions are not known to us yet. More research is needed to answer questions concerning interactions of low levels of exposure from RF/MW radiation on plants and other living organisms.

Since safety levels for this type of radiation recommended by many organizations are based on the thermal interactions only, possible effects due to other interactions should not be ignored.

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