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Plant irradiation device in microwave field with controlled environment

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ABSTRACT

Plant irradiation during the germination period, by using environmental low level microwave radiation (known as electrosmog) alters the plant germination and the growing process. In order to analyze if such a subtle effect is generated only by the microwave irradiation, the environmental parameters (light, temperature, and humidity) must be kept identical for the reference and the irradiated lot. This is a difficult task because the humidity and temperature are interrelated. In order to study the plant behavior under microwaves low power irradiation, the paper describes the design, manufacturing and operating process and device performances on plant growth. To this end, a low power microwave field (average microwaves power density of 3.8 mW/m^2) under controlled environmental parameters is used. The device consists of a reference chamber (R) and a microwave irradiation chamber (I), of 0.5 m^3 volume each one, equipped with access doors. The irradiation chamber ensures microwave field distribution with programmable power, frequency and bandwidth in the most commonly used standards for network communication such as: Global System for Mobile Communications (GSM900/1800), Code Division Multiple Access (CDMA), the third generation of mobile telecommunications technology (3G) or 2.4/5 GHz Wireless Local Area Network (WLAN). Both chambers provide a radiofrequency (RF) shielding (at least −60 dB) against and toward outside, so the electrosmog is shielded and does not interfere with the inner environment. Both chambers are equipped with performing temperature/humidity sensors and controlled LED lighting system (maximum 400 $\mu mol\, cm^{-2}\, s^{-1}$) with a uniformity of ±5 $\mu mol\, cm^{-2}\, s^{-1}$ measured at the bottom level of the chamber. An embedded system (microcontroller) measures the temperature and humidity and proceeds continuously to match the humidity into the chambers pair with less than ±1.5% relative humidity (RH) difference, by using a low flux exhaust ventilation process through a simple innovative method. The accuracy of the temperature measurement is better than ±0.2 °C. Humidity and temperature data set are logged (with programmable acquisition rate) during the whole experiment and can be read later by a personal computer. To identify the influence of microwave treatment on bean seeds and plants development, three growing experiments were settled, based on 122 bean seeds each. The number of germinated seeds (determined each day during 8 days of experiment), the germination energy (GE [%]) of the seeds, the length of stems (SL) and roots (RL), the germination (G) [%], the seedling vigor index (SVI) and dry matter content (DM%) have been measured and computed. The obtained data showed significant increase for all parameters on microwave irradiation condition.

1. Introduction

The treatment of the plants and seeds using high or low power microwave irradiation is quite known among the researchers but the results are controversial. These two types of microwave irradiation (using high or low power) create very different results. High power microwave irradiation induces a thermal effect, thus it can be used safely for treating seeds and grains only, for a short period of exposure. Low power microwave radiation does not alter irreversible the plant structure, being suitable for long time irradiation exposure during plant growing. The arguable results for low power microwave irradiation experiments relies mostly in the poor control of the experimental conditions, where the environmental parameters (light, temperature, humidity) are not entirely known and the microwave distribution field is not fully characterized.

The effect of low power electromagnetic microwave irradiation on seed germination and plant growth was studied by Oprica (2008), on the catalase and peroxidase activity in rape germinating seeds, using a microwave generator at 10.75 GHz and a horn antenna with a power density lower than 1 mW/cm^2. Skiles (2006) proposed the hypothesis that there is no difference between

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the plants exposed and not exposed to low power microwave field. The experiment showed that under controlled environment, there was no difference in chlorophylle content in leafs of alfalfa after microwave exposure at 2.45 GHz and low intensities from 0.5 to 1.2 mW/cm^2. However the microwave irradiation protocol used, based on wave reflections in open space (where the electrosmog exists) is debatable.

Tylkowska et al. (2010), proposed the use of high power microwave radiation in order to reduce *Penicillium* spp. on/in bean seeds. In this case, the common bean (*Phaseolus vulgaris* L.) seeds were exposed to microwaves in a microwave oven (650 W, 2450 MHz) for a variable time of 15–120 s. Cretescu et al. (2013), used a variable power magnetron MWG20H at 2.45 GHz on barley seeds exposed up to 20 s with 400 W and 720 W. However, the microwave power field has been estimated at 20 kW/m^3 and 36 kW/m^3 respectively, but not measured. In order to determine the effects of the microwave radiation on the inhibition of seed germination, Velàzquez-Marti et al. (2006) tested a microwave distribution system with a waveguide fed by one 4 kW magnetron, designed to treat a large soil surface and volume. Then, the irradiation of buried seeds in trays was performed by using a prototype continuous oven with four lined magnetrons of 1 kW each, in order to slightly increase the temperature of the soil and seeds. Xiaogang et al. (2014) studied the changes induced in protein molecular structures of barley grains after 3 min and 5 min exposure in power microwave field (2450 MHz and 1.33 W/g). The results showed an improvement of the nutritive value and utilization of crude protein in barely grains. Martinez Solis et al. (2014) shows that power microwave irradiation (using a Panasonic microwave oven and 10, 20 and 30 s exposure) could be a useful method for significantly reduces fungi presence on seeds of four wheat varieties (Tlaxcala, Batán, Rebeca, and Triunfo). Reddy et al. (2000) observed that seed germination and seed vigor can be affected negatively during high power microwave irradiation for long exposure sessions. Radzevicus et al. (2013) evaluate the effect of high pulsed power microwave field (4 μS pulse at 25 Hz, 9.3 GHz and 80 kW microwave power) on seed germination and seedlings (tomato, carrot and radish). Irradiation took place inside a waveguide. Significantly irradiation effects where observed an all seeds. As seen above, there are a large number of experiments involving either low or high power microwave field, each using independent microwave irradiation protocols.

Our patented device (Surducan et al., 2008, 2007) presented in this paper was used in its early development stage for various low power microwave irradiation experiments conducted at INCDTIM Cluj-Napoca (Lung, Surducan, Stan, Soran). Lung et al. (2013), investigated the effect of low power microwave on the concentration of phenolic compounds from plants. The results showed that the concentration of total flavonoids and total phenolic acids is higher in irradiated plants compared to the non-irradiated plants. In the experiment conducted by Surducan et al. (2013), the effects of low power microwave irradiation, at 2.45 GHz, on plant samples, was studied. The microwave power level used in their experiment was identical with wireless LAN communications. Reference and irradiated plants were phenotypically similar, but the growth was strongly correlated with microwave irradiation. Another study (Stan et al., 2014) found a variation of the ascorbic acid content in leaves of parsley, dill and celery plants grown in low power microwave fields at two microwave frequency domains: GSM and WLAN. The percentage increase in ascorbic acid content of irradiated plants reported to reference batch plants was calculated. Soran et al. (2014) studied the influence of low power microwave irradiation using frequency bands and amplitudes corresponding to wireless router (WLAN) and mobile devices (GSM), on leaf anatomy, essential oil content and volatile emissions in *Petroselinum crispum*, *Apium graveolens* and *Anethum graveolens*. The results showed a direct relationship between microwave-induced structural and chemical modifications of the three studied plant species. Important differences were identified by Lung et al. (2013a), on irradiated plant compared with control plants, in the caffeic acid, rosmarinic acid, luteolin, naringenin and apigenin amount. In terms of stress caused by irradiation with microwaves, Lung et al. (2013b) investigated the effect of low power WLAN microwave radiation on chlorophyll pigments from *Ocimum basilicum* L. The experiment included reference (no microwave), microwave-stressed plants and control plants (growth in normal condition). The content of chlorophylls a and b from plants subjected to microwaves was smaller than in the reference plants.

Despite the large number of published papers discussing the influence of the electromagnetic (EM) radiation on living cells, the effect of low power microwave (MW) radiation in plants growth is still not entirely known (Cucurachi et al., 2013). All experiments involving plants growth in controlled environment (temperature, humidity, illumination, MW radiation) are huge time consuming and are not reproducible as expected. Precise growing plants experiments using low power microwave field for irradiation are usually carried out using either (i) two standard plant growing chambers or (ii) two anechoic chambers (one for the reference and one for the irradiated batch). However, low power microwave irradiation experiments must not be influenced by the environmental EM radiation (the electrosmog). The (i) option fails the radiofrequency isolation to/from the outer world (standard plant growth chambers (LCG5201; KWB-240; SGC120) are not anechoic) while the (ii) option fails the precise internal environment control requirement (anechoic chambers LUF have no uniform light, humidity and temperature control). Even if two standardized plant growing chambers are modified to be anechoic (which is a very difficult approach) it's almost impossible to maintain the same environment parameters in the same period of time, in two traditional growing chambers without customization of the automation control. Such customization is expensive. To avoid the listed problems above, we choose to design and manufacture our proprietary low cost plant growing chambers in a few improved variants until the optimized version presented here met the requirements of both anechoic and growing chambers. As far we know, such device is not available today on the market for research purposes. To correct this deficiency, we have imagined this device for precise plant growth experiments in low power microwave field. The device is composed by a reference chamber (R) and an irradiation chamber (I), both anechoic and the same size. It is moveable and can support the growth of a varied number of plants from the germination stage, to about 10–12 cm tall. Since the chambers are quasi-closed, the internal temperature and relative humidity cannot be controlled simultaneously as demonstrated by Eq. (1).

$$U_w(t) = \frac{e}{e_w(t)} \cdot 100\% \tag{1}$$

where

$U_w(t)$ = relative humidity (RH) at a given temperature
e = partial vapor pressure in air
e_w = saturated vapor pressure above water at a given temperature

The temperature defines the saturation vapor pressure (Lawrence, 2005). The Magnus Eq. (2) shows that the saturation water vapor pressure changes exponentially with the temperature.

$$e_w(t) = \alpha \exp\left(\frac{\beta \cdot t}{\lambda + t}\right) \tag{2}$$