Characterization of Uniform Electromagnetic Field Exposition System in Optimizing Growth Characteristics of Mung Beans (*Vigna radiata* L.) and Water Convolvuluses (*Ipomoea aquatica* Forssk.)

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1. Introduction

Many methods to facilitate crop yields have been tested specifically aiming at improving the seed germination and the seedling growth performances, such as the chemical processes [1]-[2], and the physical treatments [3]. The use of electromagnetic field as a growth influencing factor (GIF) has drawn much interest in recent years. In [4] and [5], the authors utilized electromagnetic field generators to produce uniform magnetic fields and observed significant increases in speed of germination and seedling growths of cork oaks and chickpeas, respectively. The report in [6] has shown the potential of applying non-uniform electrical field from the corona discharge in maximizing carrot, radish, beet, beetroot and barley seed germinations and viabilities.

Mung beans (*Vigna radiata* L.) have become one of the world famous crops and are commercially cultivated worldwide across Asia, South Europe, and Southern America. Water convolvuluses (*Ipomoea aquatica* Forssk.) are highly demanded green leafy vegetables and mostly available in Southeast Asia due to favorable climate and wet soil conditions. Seeds of both plants are physically different in coat thickness and size. So far, no investigation under uniform electric fields and data on such plants are available. For this study, the objective was to determine the effect of electromagnetic treatments of mung beans and water convolvuluses on seedling growth under laboratory conditions. The paper is organized as follows. We first introduce the uniform electromagnetic field exposure system characterized through the measurement. We then report the results through observations of the seedling growth after uniform electromagnetic field treatments. The optimum treatment parameters, such as the field strength, frequency, and treatment duration are determined for maximum seedling growth enhancement.

2. Exposure Chamber Characterization

Fig. 1(a) shows the laboratory-assembled exposure chamber (50 × 50 × 30 cm³) with 50-Ω characteristic impedance. The chamber was designed based on the concept of a transverse electromagnetic (TEM) cell that offers a closed environment for field exposures and a capability of shunning internal field reflections. The design considerations include the voltage standing wave ratio (VSWR) level in frequency domain and the distribution of the electric fields inside the chamber. Fig. 1(b) shows the measuring method of the VSWR using a vector network analyzer MS 4640A (Anritsu Corporation) where the associated result from DC to 1.0 GHz is shown in Fig. 2(a). The solid arrows indicate the resonant frequencies verifying that the appropriate operating area resides in the resonance-free region between DC and 450 MHz (VSWR < 2.0). As indicated by the white arrows, the frequencies of interest in our study were 425 MHz and 300 MHz. The VSWRS of
1.06 and 1.5 at 425 MHz and 300 MHz, respectively, ensures no presence of field non-uniformity and undesirable effects from the cavity resonances, providing the perfect conditions for field exposures.

Electric field distributions inside the chamber can be evaluated using the setup shown in Fig. 1(c), comprising of a HP 83732B signal generator (Agilent Technologies) and a HP 8593E spectrum analyzer (Agilent Technologies). The parameter \( d \) denotes the depth of the chamber measured from the ceiling towards the center in the x-direction. Measurement positions are associated with the coordinates shown in the inset of Fig. 1(a) and the depth \( d \). Figs. 2(b) and (c) show the measured field distributions at 300 MHz and 425 MHz, respectively. The electric field intensities are highest near the center position (dotted-lines) for both frequencies and are relatively constant along the y-direction even though, at 300 MHz, some distortions can be observed at positions 4 and 5. The measured results of both VSWR and field distribution verify the feasibility of the constructed chamber in accommodating the exposure.

3. Electromagnetic Field Exposures and Results

The high-quality seeds from both plants were hand-graded, cleaned by rinsing with fresh distilled water, and divided into 48 groups of 6 seeds. There were a total of 16 experimental sets through 8 combinations of exposure parameters for each variety of seeds. Each set consists of three groups of treatment replications and three groups of non-treated seeds as associated controls. After seed preparations, each group except the control was situated at the center of the septum (the inner conductor) inside the treatment chamber and applied with uniform continuous sinusoidal signals with two levels of power strengths (1 and 100 mW), two exposure durations (1 and 2 h), and two sets of frequencies (300 and 425 MHz). The experimental setup is shown in Fig. 3 through using a HP 83732B signal generator (Agilent Technologies) and a HP 8447D RF amplifier (Agilent Technologies).

Following uniform field exposures, both treated and associated control seeds were evenly spread between two layers of moistened tissue papers in the same clean plate at opposite ends as
shown in Figs. 4(a) and 4(b). The laboratory condition was maintained with a temperature of 25 ± 1 °C under a 14 h light/10 h dark regime. The tested materials were kept moist throughout germination by spraying them with 25-ml distilled water twice a day. The growth and development were monitored through an observation of the seedling length and recorded everyday for a period of 7 days using a vernier calliper as shown in Fig. 4(c). After a week of plate planting, the growth performances of all exposure sets were determined and compared through statistical analyses.

Figure 3: Uniform electromagnetic field exposure setup.

Figs. 5(a) and 5(b) show the average seedling lengths (mm) of 7-day-old mung beans and water convolvuluses, respectively, from eight experimental sets of both treated and control groups at 300 MHz. For certain values of exposure parameters, continuous electromagnetic field application on the seeds can enhance the growth performances compared to those of unexposed seeds. It can be observed that the mung beans exposed with a combination of 1 mW/2 h grew significantly better by 30.8 % (P < 0.01, one-tailed paired sample t-test) compared to the controls. For the exposure of water convolvuluses, the data showed significant increases of 28.3 % and 16.5 % (P < 0.05, one-tailed paired sample t-test) with combinations of 1 mW/2 h and 100 mW/2 h, respectively, in comparison with the controls. Other combinations did not influence the seed growth performances for both plants.

Similarly, the average seedling lengths (mm) of 7-day-old mung beans and water convolvuluses exposed at 425 MHz are shown, respectively, in Figs. 6(a) and 6(b) for all three replications and controls. In mung bean exposures, a combination of 1 mW/1 h improved the growth performance by 12.5 % (P < 0.05, one-tailed paired sample t-test). Also, a highly significant increase of 48.5 % can be observed with a combination of 100 mW/1 h (P < 0.01, one-tailed paired sample t-test). In case of water convolvuluses, a combination of 1 mW/2 h caused a highly
significant increase of 20.4 % (\(P < 0.01\), one-tailed paired sample t-test) compared to the controls. The seed growth performances for both plants were unaffected with other exposure combinations.

Figure 6: Seedling lengths (mm) of 7-day-old (a) mung beans and (b) water convolvuluses after electromagnetic exposure at 425 MHz. (* = \(P < 0.05\), ** = \(P < 0.01\)).

4. Discussion and Conclusion

In this study, we have exposed two varieties of seeds, i.e., mung bean (\textit{Vigna radiata} L.) and water convolvulus (\textit{Ipomoea aquatica} Forssk.), to uniform continuous electromagnetic field. The objective was to determine the enhancing effect in the plant growth, if any, through electromagnetic field exposure of seeds for given sets of exposure parameters where they are power strength, exposure time, and frequency. The experiments were conducted under laboratory conditions through exposure chamber.

The overall experimental results show that the seedling developments of both plants react towards uniform electromagnetic fields, depending on the exposure parameters. At 300 MHz, both seed varieties required 2 h of exposure duration to influence the seedling growth while, at 425 MHz, mung beans demanded less energy, which is related to the product of the power strength and exposure duration, than that of water convolvuluses to have effects on the growth performances. This would attribute to the seed coat’s physical thickness where the thicker coat of water convolvulus is proportional to more energy uptake.

In conclusion, it has shown that continuous electromagnetic field can improve the growth characteristics of the mung beans and the water convolvuluses. The effectiveness of the growth enhancement can be controlled by selecting appropriate exposure parameters. The enhancement efficiency also depends on the plant variety. The highest raise in plant growth development of 48.5 % can be observed from mung bean treatment when an exposure combination is 100 mW/1 h/425 MHz.

References