A dielectric barrier electrode of a uniform AC electric field effect on roselle root length

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Abstract

This paper presents the effect of a uniform alternating current (AC) electric field on average root length of roselles germinating from seeds. The electric field in this experiment is between 0-4 kV/cm, which is generated by a high voltage AC source 0-2.3 kVAC, 50 Hz, which in turn is connected to an electrode plane with a dielectric barrier. The purpose of this experiment was to determine the relationship between uniform AC electric field energy on roselle seeds that were activated by a process over 10, 20 and 30 minutes and based on results of the average root length of the roselle after one week. The results show that when the time increases, it causes a small increase in average root length and then begins to decrease. When an increased electric field affects the result of the average root length, it increases and then begins to decrease. Roselle seeds without the activated process have an average root length of 5.01 cm, while roselle seeds that are activated by an electric field of 3 kV/cm at an activated time of 20 minutes. Roselle seeds with the activated process have the greatest average root length, with 9.07 cm or 79.24%. All of the results contribute to the development of a roselle seed activated device that can be used for the improvement of the roselle planting process in Thailand.

Keywords: electric field, dielectric barrier, roselle seeds, activated

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Introduction

It is well known that Thailand is a major producer of roselle products (Figure 1). which is of importance to the world market (OAE, 2007). For quality dried roselle products there is a market demand because of the benefits of roselle in food, which has a good taste as well as being a medicinal herb to provide a lot of health benefits. For example, it can be used to treat high blood pressure by reducing blood viscosity, protect Benign Prostatic Hyperplasia (BPH) and reduce dyslipidemia (Thavorn *et al*., 2006). According to a survey conducted in Thailand, it was found that farmers are most likely to plant Sudan Roselle because of its ability to withstand environmental conditions of the country. They also provide a good yield with an average cost per 1,600 m^3 of 115$ and 1,100-1,500 kg of produce (Bureau of Agricultural Economic Research, 2007).

At present, because of the rising costs of living coupled with the expansion of communities causing limited planting areas, it has resulted in lower yields. It is necessary to have a good plan for cultivation, which can be derived from a study of suitable soil and climate for economic crops. Nakhon Sawan province, Thailand, is known for its suitable weather between August and December to have the most production from crops (Research and development of soil quality, 2005). However, due to global warming the weather conditions are unstable, leading to the yield not being stable between August and December. This has the effect that farmers must use a large number of chemicals for both pesticides and crop production that leads to health hazards and pollution to the environment (Sanklom *et al*., 2013).

From the study of engineering research on agricultural productivity optimization, the uniform application of electric fields to activate rice grain at a suitable electric field energy and activated time was found. The results showed that the rate of seed germination percentage root length and germination index increased more than rice grain without activation. The electric field at 3 kV/cm conducted the best result (Saejung *et al*., 2012)

All of this had led to this paper's objective to use clean technology to reduce the amount of chemicals in agricultural activity and improve the performance of roselles by seeds being activated with an electric field before the plantation process. The purpose of this paper is to analyze suitable electric field energy and activated time that affects an increased average root length of germinated seeds in one week. All of the results are important to develop a prototype of a roselle seeds activated device with the purpose of improving the roselle planting process in Thailand.

Figure 1 Roselle seeds.

Methodology

I Theory

1.1 Uniform electric field (Kuffel and Abdullah, 1997)

Uniform electric field intensity is used in the experiment as follows by Eq. (1):

$$E_{max} = \frac{V}{d \cdot \eta^*} \quad (1)$$

An electric field occurs between two electrodes separated depending on the configuration of electrodes and gab distance.

1.2 Dielectric barrier discharge (DBD) (Kuffel and Abdullah, 1997)

Dielectric barrier discharge is the electrical discharge between two electrodes separated by an insulating dielectric barrier that can protect the breakdown by a high electric field intensity at a sharp edge.

An electric field that occurs on dielectric barrier material (Figure 2) can determine the electric field as follow Eqs. (2)-(3):

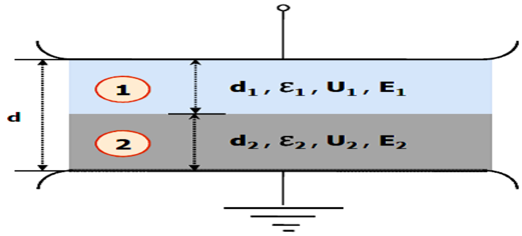


Figure 2 Electric field on dielectric barrier material.

$$E_1 = \frac{U}{d_1} \cdot \frac{1}{\left(1+\frac{\varepsilon_1}{\varepsilon_2} \frac{d_2}{d_1}\right)} \quad (2)$$

$$E_2 = \frac{U}{d_1} \cdot \frac{\varepsilon_1/\varepsilon_2}{\left(1+\frac{\varepsilon_1}{\varepsilon_2} \frac{d_2}{d_1}\right)} \quad (3)$$

Where E1 is the electric field stress in dielectric barrierd is charge (acrylic) and E2 is the electric field stress in air.d1 is the dielectric barrier thickness and d2 is the air gab thickness. ε_1 is the permittivity of acrylic and ε_2 is the permittivity of air. U is the applying a high voltage.

1.3 Electroporation (Weaver, 1995)

Electroporation occurs when a supply of high-voltage to electrodes generates an electric field that overcomes the barrier of the cell membrane. This just surpasses the capacitance of the cell membrane, transient and reversible breakdown of the membrane. The electric field causes a breakdown of the membrane instead of the critical electric field (E_c). This is important to consider for the electric field in the experiment is not more than E_c (Figure 3).

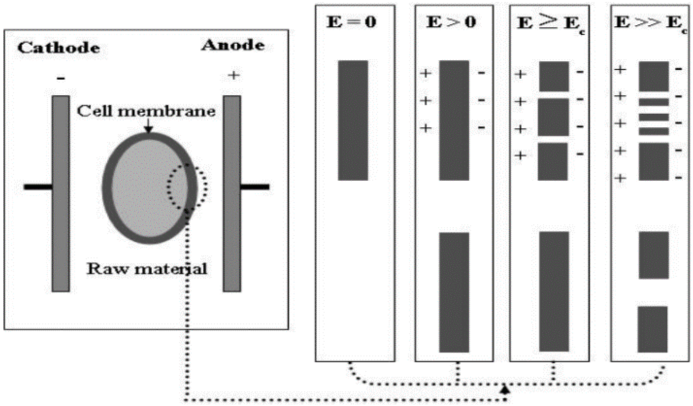


Figure 3 Electroporation mechanisms.

II. Experiment setup

2.1 Diagram of experiment setup

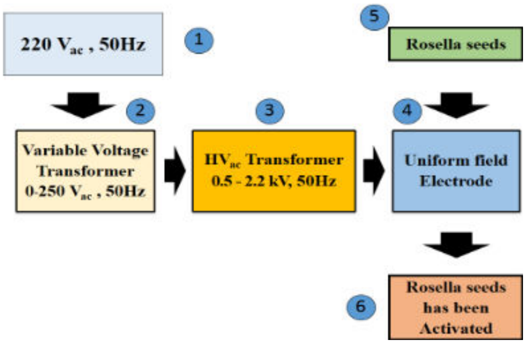


Figure 4 Diagram of experiment setup.

(Figure 4) shows the overall sequence of the experiment. Number 1 is the voltage source 220 V_{ac}, 50 Hz supply to a variable voltage transformer 0-250 V_{ac} in number 2. That is connected to a high voltage AC transformer at number 3 to generate a high voltage AC rated 0.5-2.2 kV, 50 Hz to be supplied to a uniform field electrode at number 4. This in turn generates the electric field to activate roselle seeds at number 5. The roselle seed shave been activated in number 6, which is the objective product to observe in this experiment.

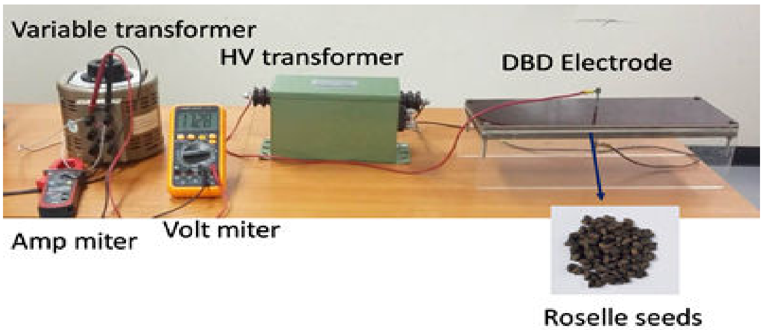
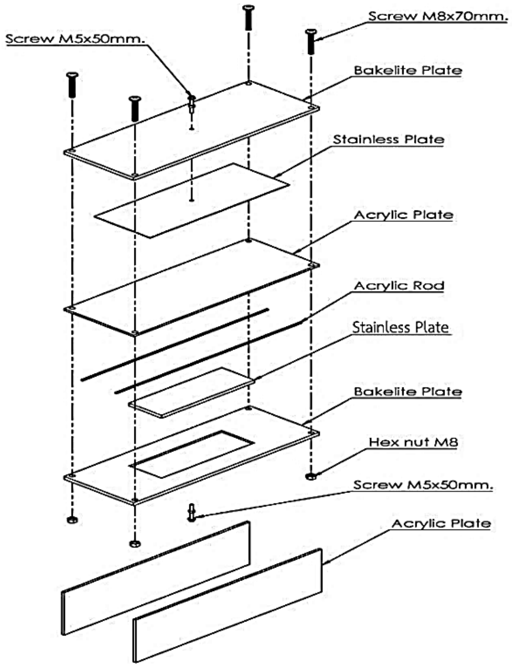


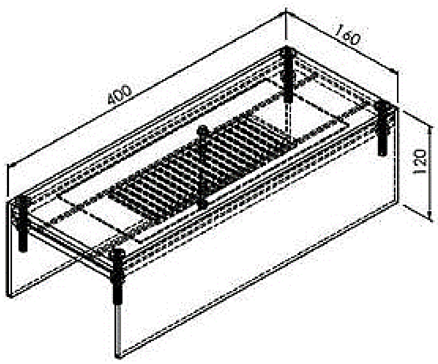
Figure 5 Experiment setup.

2.2 Electrode configuration

The electrode has been designed in this experiment to have the capacity for 200 roselle seeds, as shown (Figure 6).



(A) electrode assembly



(B) electrode configuration

Figure 6 Electrode assembly and configuration.

2.3 Electric field determination

The electrode designed in (Figure 6) can be used to analyses the electric field distribution by a simulation program based on FEM theory. (Figure 7) shows the voltage across separate electrodes, (Figure 8) the electric field distribution between separate electrodes and (Figure 9) the relationship of the electric field via the gab of the electrode dimension.

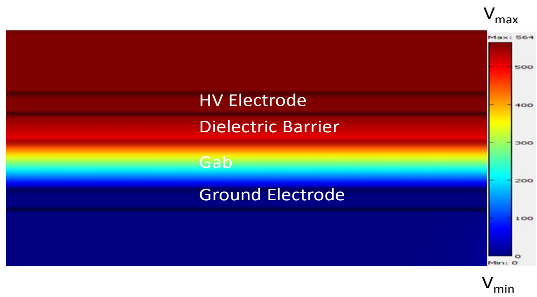


Figure 7 Voltage across separate electrodes.

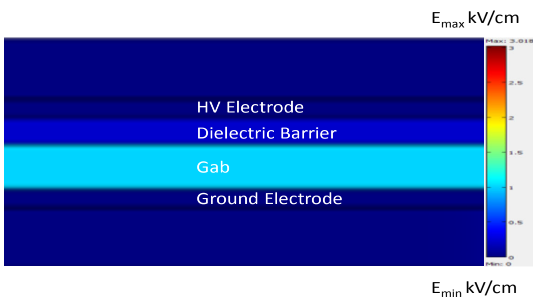


Figure 8 Electric field distribution between separate electrodes.

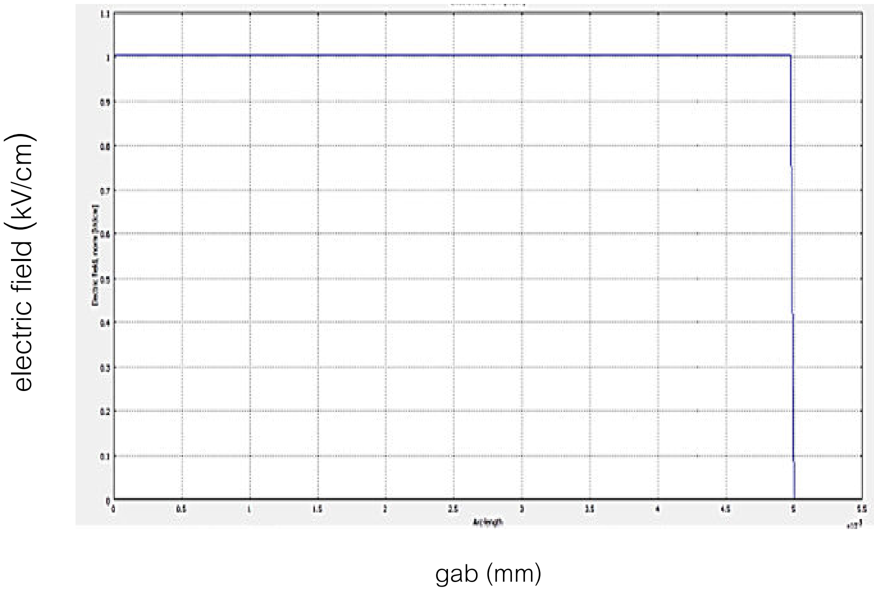


Figure 9 Relation of electric field via the gab of electrode dimension.

Table 1 Relation of voltage and electric field in experiment.

electric field (kV/cm)	HV_{AC} (V)
1	564
2	1129
3	1694
4	2258

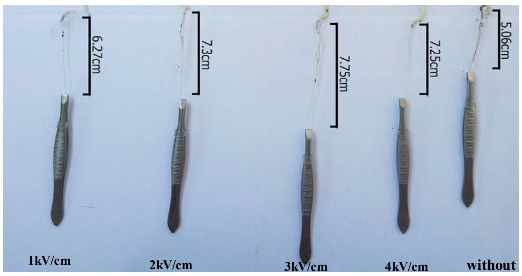


Figure 10 Sample of root length has been measure by vernier caliper.

Results and discussion

The purpose of this experiment is to observe the relationship between the average root length germination in one week, with and without being activated by uniform AC electric fields 0, 1, 2, 3 and 4 kV/cm at a deferent time of 10, 20 and 30 minutes (Table 1).

The results of the average root length via electric field and duration time in this experiment can be measured from 100 samples of seeds by vernier caliper. An example of the result is shown in (Figure 10).

(Figure 11) shows that when the electric field increases, it has the effect of increasing the average root length of the roselle. Roselle seeds that were activated at an electric field of 3 kV/cm provided the best results with an average root length of 9.07 cm, compared to being without the activated process, which was an average 4.01 cm or 79.24%.

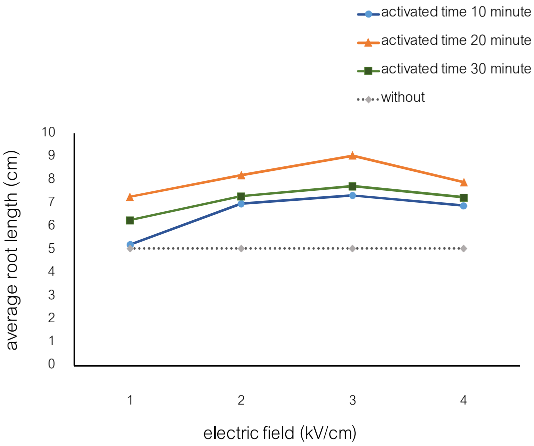


Figure 11 Relationship of average root length by varied electric fields.

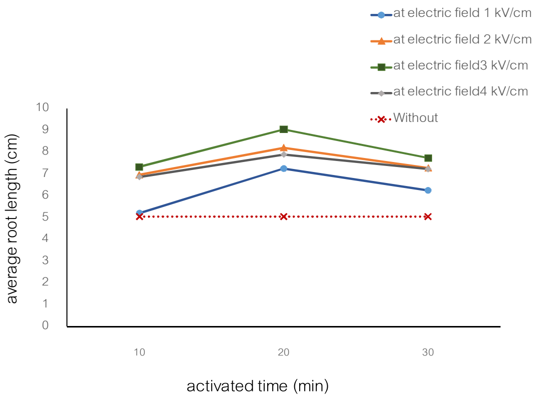


Figure 12 Relationship of average root length by varied activated time.

(Figure 12) shows the results of the same electric field when increasing the activated time. This had the effect of increasing the average root length of the roselle. Roselle seeds that were activated for a duration time of 20 minutes had the best results in this experiment.

Conclusion

The result from the experiment studying the effects of a uniform AC electric field of a dielectric barrier electrode on roselle seeds root length shows that when an electric field increases, it affects average root length of the roselle by increasing it before starting to decrease it when the electric field level is more than 3 kV/cm. The increased activated time causes the average root length to increase and then start to decrease when the activated time is more than 20 minutes. The result in this experiment can define a suitable applied electric field and a suitable activated time to generate an AC electric field from dielectric barrier electrode to roselle seeds activated was an electric field 3 kv/cm with an activation time of 20 minutes. This provided the best result in this experiment with an average root length of 9.07 cm, which was more than without the activated process, with 4.01 cm or 79.24%. All of the results are important to develop a prototype of a roselle seeds activated device to improve the roselle planting process, or, can be applied to another plant that germinates from seeds and can help industrial agriculture in Thailand by new innovations in technology.

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