

Quantitative Analysis of Plant Growth Exposed to Electric Fields

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Abstract

Electromagnetic radiations present in the environment has a profound effect on the growth of vegetable plant primarily grown under the high power transmission lines. The high electric field generated due to the ultra high voltage causes the increase and reduction in the size of the plants. Numerous research has been carried out to investigate the effect of electric field on the plants. However, the knowledge in term of quantitative analysis on the effect of electric field on the growth of vegetables is not entirely understood. Thus, this paper presents a study conducted to investigate the effect of high voltage DC electric fields on the young vegetable growth namely 'Choy Sam' and bean sprout. The experimental setup was designed which composed of two parallel plate electrodes. An electric field intensity of 38 kV/m was supplied between those two plate electrodes, and it was applied to the young vegetables. This research was focused on the percentage of germination and growing rate of young vegetables. The experiment was divided into two parts. The first part was to test whether there was an effect towards young vegetables exposed to or not exposed to electric fields. The second part of the experiment was to test the effect of electric fields treated water towards young vegetables. The numbers of seed, temperature and relative humidity were controlled. The changing of vegetables was observed for 8 hours per day for two weeks (Choy Sam) and one week (bean sprout). The growth of the young vegetables during exposure was calculated by using statistical methods. The analysis of the results showed that the electric fields and the electric fields treated water have influenced the germination rate and height of stems of both young vegetables causing the increase in stem height.

Keywords: Electromagnetic, Electric Field, DC High Voltage, Choy Sam, Bean Sprout

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1. Introduction

One of the sources of the electric fields and magnetic fields is the transmission line. In the last few decades, many researches have been performed to observe the effect of electric fields towards the human body and animals. This would probably improve the exposure of the electrical fields, magnetic fields and electromagnetic fields (EMF) for high voltage applications. Conversely, its effect on a human is not just impairments but it also can give more benefits in several approaches if it is well controlled. Since three decades ago, EMF such a various frequency ranges have been used in physiotherapy for the treatment of several diseases.

The recent experimental results of the previous studies indicated that the bean sprout exposed to the vertical electric field direction has a better growth compared to the horizontal part of the electric field direction [1, 2]. The investigation was carried out to determine whether by placing the soybean seeds in electric field for a certain period of time would affect their germination rate. If it happens, the period between planting and emergence can be reduced [3]. The initial appearance usually means healthier plants and energy producing higher yields [4]. Therefore, the use of electrical energy to biological organisms has the potential to increase the production of food. This can lead to the uses of electricity to stimulate the growth of the fair organism or use it to slow down the growth or reproduction of unwanted organisms. If either of these approaches yields positive results, humans would benefit [4]. The effect of electric field treated water towards young vegetables which were a new kind of method has been carried out to give more significant results.

Furthermore, Mahajan and Pandey [5] investigated the effect of the electric field with varying voltage on the absorption of water and germination of soybean seed. The study was conducted to find the resonant electric field that has a significant effect on the proliferation and the growth of soybean seed. It was found that seedlings were sensitive to some specific value of magnetic field.

Since there were numerous studies on the effect of electric field, magnetic field and electromagnetic field on human, animal and plants but the quantitative analysis of the effect of electric field on plants is still lacking and not fully understood. The quantitative measure of plant changes towards exposed electric field would give more definitive understanding rather than subjective comparison.

Thus, in this study, we focused on the effect of DC electric field on the growth of young vegetables namely '*Choy Sam*' and bean sprout. Bean sprout was chosen due to its simplicity and very fast growth rate. Also, the statistical analysis was performed to yield more quantitative and definitive understanding towards the effect of the electric field as well as definitive comparison.

2. Experimental Setup

For the first part of the experiment, the seed of young vegetables were planted in a few plastic boxes at the room temperature. Three implemental boxes were used, and three are a total of 50 seeds of '*Choy Sam*' were planted in the boxes. Special black soils were mixed with red soils with the ratio 3:2 were used for plant growing where the amount of water was controlled. Apart from that, an implemental box was used, and total 40 seeds of bean sprout were planted in the box. Cotton-wool was used for bean sprout growing where the amount of water is controlled. Then, these boxes of seeds are put under exposure to electric fields. The same amount of seeds, boxes, soils and cotton-wool were prepared as a reference. The comparison of plant growing between with and without electric field was done. This research focused on the percentage of germination and the height of stems. Temperature and relative humidity were controlled. The room temperature was about 32°C. A 38 kV DC voltage was applied to obtain electric field intensity of 38 kV/m.

For the second part of the experiment, the preparation for the seeds of '*Choy Sam*' and bean sprout, boxes, soils and cotton-wool were similar to the first part of the research. The reference set of seeds that used in the first experiment was used as a reference set in this experiment. The comparison of plant growing between with and without electric fields treated water was done. This research focused on the percentage of germination and the height of stems. Temperature and relative humidity were controlled and similar to the first experiment. A 38kV DC Voltage was applied to obtain electric field intensity of 38kV/m. Firstly, the main supply was attached to variac. The function of variac was to adjust the input voltage. Then, the variac was connected to HV transformer that was used to step-up the input voltage. After that, the HV transformer was attached to the rectifier. The diodes in rectifier were used to convert AC to DC supply, and the capacitor was used to smooth the ripple voltage. The low voltage amp was used to reduce the voltage to a particular value and then only be connected to a digital multimeter. From the rectifier, it was then attached to the two-plate electrodes. The upper aluminium plate (anode) was connected to the cable between the rectifier and the lower aluminium plate (cathode) was connected to earth. The distance between these two aluminium plates was 1 m. The cable from the rectifier was attached from the top to the anode and supported by bushing so that the direction of electric fields was from upper plate to lower. There were no sharp edges at the four corners of upper aluminium plate and four metal balls were screwed at the four corners to reduce the effect of corona when high voltage was supplied to the upper plate [6].

3. Experimental Results

3.1. Comparison between the Percentage of Germination and Growing Rate of Plants with and without Electric Fields

Firstly, the percentages of germination and growth rate of '*Choy Sam*' were observed. For the percentage of germination, the result is shown in Table 1.

Table 1. The percentage of germination for 'Choy Sam' which exposed to electric fields and non-electric fields

| Time | Percentage of germination with electric fields (%) | Percentage of germination without electric fields (%) |
|--------|--|---|
| Day 1 | 0 | 0 |
| Day 2 | 34 | 14 |
| Day 3 | 74 | 72 |
| Day 4 | 74 | 74 |
| Day 5 | 76 | 74 |
| Day 6 | 76 | 74 |
| Day 7 | 76 | 74 |
| Day 8 | 76 | 74 |
| Day 9 | 76 | 74 |
| Day 10 | 76 | 74 |
| Day 11 | 76 | 74 |
| Day 12 | 76 | 74 |
| Day 13 | 76 | 74 |
| Day 14 | 76 | 74 |

For the growth rate, the statistical methods were used [7, 8]. The result of hypothesis test involving differences of two population means, $\mu_1 - \mu_2$ ($n_1 \geq 30, n_2 \geq 30$) is shown in Table 2. The 30 height plants were chosen in this method. The analysis conditions of the collected data are as follows:

1. $n_1 = n_2 = 30$
2. Significance level = $\alpha = 5\%$
3. Null hypothesis is $H_0 : \mu_1 = \mu_2$
4. Alternative hypothesis is $H_1 : \mu_1 > \mu_2$
5. Reject H_0 if $Z_{\text{test}} > Z_{\alpha} = Z_{0.05} = 1.6449$

Table 2. Mean, standard deviation and Z-value of the height of stem

| Time | Mean (mm) | | Standard Deviation (mm) | | Z_{test} Value | Result |
|--------|-----------|--------------|-------------------------|--------------|-------------------------|-----------------|
| | E-fields | Non E-fields | E-fields | Non E-fields | | |
| Day 1 | 0 | 0 | 0 | 0 | 0 | $\mu_1 = \mu_2$ |
| Day 2 | 1.33 | 0.30 | 1.49 | 0.59 | 3.52 | $\mu_1 > \mu_2$ |
| Day 3 | 9.93 | 8.23 | 3.12 | 1.77 | 2.58 | $\mu_1 > \mu_2$ |
| Day 4 | 38.56 | 38.66 | 4.52 | 2.78 | -0.10 | $\mu_1 = \mu_2$ |
| Day 5 | 58.66 | 57.90 | 5.66 | 4.12 | 0.59 | $\mu_1 = \mu_2$ |
| Day 6 | 73.53 | 73.36 | 6.54 | 5.35 | 0.10 | $\mu_1 = \mu_2$ |
| Day 7 | 78.90 | 78.73 | 7.59 | 6.85 | 0.09 | $\mu_1 = \mu_2$ |
| Day 8 | 83.20 | 81.83 | 8.08 | 7.57 | 0.68 | $\mu_1 = \mu_2$ |
| Day 9 | 85.03 | 83.20 | 7.77 | 8.19 | 0.89 | $\mu_1 = \mu_2$ |
| Day 10 | 86.43 | 84.06 | 7.95 | 7.91 | 1.15 | $\mu_1 = \mu_2$ |
| Day 11 | 87.10 | 84.70 | 8.13 | 8.37 | 1.13 | $\mu_1 = \mu_2$ |
| Day 12 | 87.83 | 84.96 | 8.14 | 8.38 | 1.34 | $\mu_1 = \mu_2$ |
| Day 13 | 88.10 | 84.96 | 8.05 | 8.38 | 1.48 | $\mu_1 = \mu_2$ |
| Day 14 | 88.13 | 85.43 | 8.02 | 8.64 | 1.25 | $\mu_1 = \mu_2$ |

The result of F-test in ANOVA is shown in Table 3. 30 highest plants were chosen in this method. The analysis conditions of the collected data are listed as follows:

1. $n_i = n_k = 30$
2. $N=60, k=2$
3. Significance level = $\alpha = 5\%$
4. $H_0 : \alpha_1 = \alpha_2 = 0$ Versus $H_1 : \alpha_i \neq 0$
5. Reject H_0 if f value $> f_{\alpha; k-1, N-k} = f_{0.05; 1, 58} = 4.00$

Where α_i is the i -th treatment effect.

Table 3. The result of F-test in ANOVA

| Time | f Value | Result |
|--------|---------|---------------------------|
| Day 1 | 0 | No treatment effect |
| Day 2 | 12.3905 | Positive treatment effect |
| Day 3 | 6.7000 | Positive treatment effect |
| Day 4 | 0.0106 | No treatment effect |
| Day 5 | 0.3593 | No treatment effect |
| Day 6 | 0.0116 | No treatment effect |
| Day 7 | 0.0080 | No treatment effect |
| Day 8 | 0.4563 | No treatment effect |
| Day 9 | 0.7903 | No treatment effect |
| Day 10 | 1.3338 | No treatment effect |
| Day 11 | 1.2677 | No treatment effect |
| Day 12 | 1.8048 | No treatment effect |
| Day 13 | 2.1803 | No treatment effect |
| Day 14 | 1.5718 | No treatment effect |

The results of independence tests are shown in Table 4 and Table 5. The analysis conditions of the collected data are listed as follows:

1. Significance level = $\alpha = 5\%$
2. H_0 : the height of 'Choy Sam' and exposed/do not expose to electric fields are independent
3. H_1 : the height of 'Choy Sam' and exposed/do not expose to electric fields are dependent
4. Reject H_0 if $X^2 > X^2_{\alpha, (r-1)(c-1)} = X^2_{0.005, 1} = 3.841$

Table 4. The number of plants that the heights of stem are less than 90mm or exceeding 90mm

| Conditions | Height of stems | |
|----------------------------------|-----------------|--------|
| | <90 mm | ≥90 mm |
| Exposed to electric fields | 36 | 14 |
| Do not expose to electric fields | 40 | 10 |

Table 5. The value of O_{ij} , E_{ij} , X^2 .

| O_{ij} | E_{ij} | $\frac{(O_{ij} - E_{ij})^2}{E_{ij}}$ |
|----------|----------|--------------------------------------|
| 36 | 38.0000 | 0.1053 |
| 14 | 12.0000 | 0.3333 |
| 40 | 38.0000 | 0.1053 |
| 10 | 12.0000 | 0.3333 |
| X^2 | | 0.8772 |

Since $X^2 < 3.841$, thus we accept H_0 and conclude that the height of stems is independent on exposed/do not exposed to electric fields.

Secondly, the percentage of germination and growth rate of bean sprout was observed. For the percentage of germination, the result is shown in Table 6.

Table 6. The percentage of germination for bean sprouts that exposed to electric fields and non-electric fields

| Time | Percentage of germination with electric fields (%) | Percentage of germination without electric fields (%) |
|-------|--|---|
| Day 1 | 0 | 0 |
| Day 2 | 82.5 | 65.0 |
| Day 3 | 95.0 | 90.0 |
| Day 4 | 95.0 | 90.0 |
| Day 5 | 95.0 | 90.0 |
| Day 6 | 95.0 | 90.0 |

For the growth rate, the result of hypothesis test involving differences of two population means, $\mu_1 - \mu_2$ ($n_1 < 30, n_2 < 30$) is shown as Table 7. 20 highest plants are chosen in this method. The analysis conditions of the collected data are as follows:

1. $n_1 = n_2 = 20$
2. Significance level = $\alpha = 5\%$
3. Null hypothesis is $H_0 : \mu_1 = \mu_2$
4. Alternative hypothesis is $H_1 : \mu_1 > \mu_2$
5. Reject H_0 if $t_{\text{test}} > t_{\alpha, v} \approx 1$.

Table 7. Mean, standard deviation and t-value of the height of the stem

| Time | Mean(mm) | | Standard Deviation(mm) | | t_{test} Value | Result |
|-------|----------|--------------|------------------------|--------------|-------------------------|-----------------|
| | E-fields | Non E-fields | E-fields | Non E-fields | | |
| Day 1 | 0 | 0 | 0 | 0 | 0 | $\mu_1 = \mu_2$ |
| Day 2 | 3.90 | 1.40 | 1.02 | 0.59 | 9.44 | $\mu_1 > \mu_2$ |
| Day 3 | 7.80 | 4.45 | 2.35 | 1.31 | 5.55 | $\mu_1 > \mu_2$ |
| Day 4 | 23.75 | 16.40 | 10.48 | 7.01 | 2.60 | $\mu_1 > \mu_2$ |
| Day 5 | 87.70 | 62.05 | 24.40 | 29.63 | 2.98 | $\mu_1 > \mu_2$ |
| Day 6 | 113.10 | 84.40 | 25.24 | 33.89 | 3.03 | $\mu_1 > \mu_2$ |

The result of F-test in ANOVA is shown in Table 8. The 20 highest plants were chosen in this method. The analysis conditions of the collected data are listed as follows:

1. $n_i = n_k = 20$
2. $N=40, k=2$
3. Significance level = $\alpha = 5\%$
4. $H_0 : \alpha_1 = \alpha_2 = 0$ Versus $H_1 : \alpha_i \neq 0$
5. Reject H_0 if f value $> f_{\alpha; k-1, N-k} = f_{0.05; 1, 38} = 4.1247$

Where α_i is the i -th treatment effect.

Table 8. The result of F-test in ANOVA

| Time | f Value | Result |
|-------|---------|---------------------------|
| Day 1 | 0 | No treatment effect |
| Day 2 | 89.2857 | Positive treatment effect |
| Day 3 | 30.8690 | Positive treatment effect |
| Day 4 | 6.7873 | Positive treatment effect |
| Day 5 | 8.9279 | Positive treatment effect |
| Day 6 | 9.2253 | Positive treatment effect |

The results of independence tests are shown in Table 9 and Table 10. The analysis conditions of the collected data are as follows:

1. Significance level = $\alpha = 5\%$

2. H_0 : the height of bean sprout and exposed/do not expose to electric fields are independent
3. H_1 : the height of bean sprout and exposed/do not expose to electric fields are dependent
4. Reject H_0 if $X^2 > X_{\alpha, (r-1)(c-1)}^2 = X_{0.005, 1}^2 = 3.841$

Table 9. The number of plants that the heights of stem are less than 100mm or exceeding 100mm

| Conditions | Height of stems | |
|----------------------------------|-----------------|---------|
| | <100 mm | ≥100 mm |
| Exposed to electric fields | 22 | 18 |
| Do not expose to electric fields | 33 | 7 |

Table 10. The value of O_{ij} , E_{ij} , X^2 .

| O_{ij} | E_{ij} | $\frac{(O_{ij} - E_{ij})^2}{E_{ij}}$ |
|----------|----------|--------------------------------------|
| 22 | 27.5000 | 1.1000 |
| 18 | 12.5000 | 2.4200 |
| 33 | 27.5000 | 1.1000 |
| 7 | 12.5000 | 2.4200 |
| X^2 | | 7.0400 |

Since $X^2 > 3.841$, so we reject H_0 and conclude that the height of stems is dependent on exposed/do not exposed to electric fields.

3.2. Comparison between the Percentage of Germination and Growth Rate of Plants that Watered with and without Electric Fields Treated Water

Firstly, the percentage of germination and growth rate of 'Choy Sam' was observed. For the percentage of germination, the result is shown in Table 11.

Table 11. The percentage of germination for 'Choy Sam' which watered with and without electric fields treated water

| Time | Percentage of germination with electric fields (%) | Percentage of germination without electric fields (%) |
|--------|--|---|
| Day 1 | 0 | 0 |
| Day 2 | 16 | 14 |
| Day 3 | 68 | 72 |
| Day 4 | 68 | 74 |
| Day 5 | 68 | 74 |
| Day 6 | 70 | 74 |
| Day 7 | 70 | 74 |
| Day 8 | 70 | 74 |
| Day 9 | 70 | 74 |
| Day 10 | 70 | 74 |
| Day 11 | 70 | 74 |
| Day 12 | 70 | 74 |
| Day 13 | 70 | 74 |
| Day 14 | 70 | 74 |

For the growth rate, the result of hypothesis test involving differences of two population means, $\mu_1 - \mu_2$ ($n_1 \geq 30, n_2 \geq 30$) is shown in Table 12. The 30 height plants were chosen in this method. The analysis conditions of the collected data are as follows,

1. $n_1 = n_2 = 30$
2. Significance level = $\alpha = 5\%$
3. Null hypothesis is $H_0 : \mu_1 = \mu_2$

4. Alternative hypothesis is $H_1: \mu_1 > \mu_2$
5. Reject H_0 if $Z_{\text{test}} > Z_{\alpha} = Z_{0.05} = 1.6449$

Table 12. Mean, standard deviation and Z-value of the height of stem

| Time | Mean (mm) | | Standard Deviation (mm) | | Z_{test} Value | Result |
|--------|-----------|--------------|-------------------------|-----------------|----------------------------|-----------------|
| | E-fields | Non E-fields | | | | |
| Day 1 | 0 | 0 | 0 | $\mu_1 = \mu_2$ | 0 | $\mu_1 = \mu_2$ |
| Day 2 | 0.66 | 0.30 | 1.40 | $\mu_1 = \mu_2$ | 1.40 | $\mu_1 = \mu_2$ |
| Day 3 | 7.03 | 8.2333 | -1.62 | $\mu_1 = \mu_2$ | -1.62 | $\mu_1 = \mu_2$ |
| Day 4 | 35.96 | 38.66 | -3.36 | $\mu_1 = \mu_2$ | -3.36 | $\mu_1 = \mu_2$ |
| Day 5 | 56.60 | 57.90 | -1.02 | $\mu_1 = \mu_2$ | -1.02 | $\mu_1 = \mu_2$ |
| Day 6 | 72.36 | 73.36 | -0.56 | $\mu_1 = \mu_2$ | -0.56 | $\mu_1 = \mu_2$ |
| Day 7 | 80.23 | 78.73 | 0.80 | $\mu_1 = \mu_2$ | 0.80 | $\mu_1 = \mu_2$ |
| Day 8 | 84.90 | 81.83 | 1.54 | $\mu_1 = \mu_2$ | 1.54 | $\mu_1 = \mu_2$ |
| Day 9 | 87.26 | 83.20 | 2.01 | $\mu_1 > \mu_2$ | 2.01 | $\mu_1 > \mu_2$ |
| Day 10 | 88.33 | 84.06 | 2.11 | $\mu_1 > \mu_2$ | 2.11 | $\mu_1 > \mu_2$ |
| Day 11 | 89.73 | 84.70 | 2.42 | $\mu_1 > \mu_2$ | 2.42 | $\mu_1 > \mu_2$ |
| Day 12 | 90.36 | 84.96 | 2.62 | $\mu_1 > \mu_2$ | 2.62 | $\mu_1 > \mu_2$ |
| Day 13 | 90.80 | 84.96 | 2.82 | $\mu_1 > \mu_2$ | 2.82 | $\mu_1 > \mu_2$ |
| Day 14 | 90.80 | 85.43 | 2.55 | $\mu_1 > \mu_2$ | 2.55 | $\mu_1 > \mu_2$ |

The result of F-test in ANOVA is shown as Table 13. The 30 highest plants were chosen in this method. The analysis conditions of the collected data as follows:

1. $n_i = n_k = 30$
2. $N=60, k=2$
3. Significance level = $\alpha = 5\%$
4. $H_0: \alpha_1 = \alpha_2 = 0$ Versus $H_1: \alpha_i \neq 0$
5. Reject H_0 if f value $> f_{\alpha; k-1, N-k} = f_{0.05; 1, 58} = 4.00$

Where α_i is the i -th treatment effect.

Table 13. The Result of F-test in ANOVA

| Time | f Value | Result |
|--------|-----------|---------------------------|
| Day 1 | 0 | No treatment effect |
| Day 2 | 1.9841 | No treatment effect |
| Day 3 | 2.6410 | No treatment effect |
| Day 4 | 11.3360 | Adverse treatment effect |
| Day 5 | 1.0488 | No treatment effect |
| Day 6 | 0.3148 | No treatment effect |
| Day 7 | 0.6500 | No treatment effect |
| Day 8 | 2.3833 | No treatment effect |
| Day 9 | 4.0501 | Adverse treatment effect |
| Day 10 | 4.4606 | Positive treatment effect |
| Day 11 | 5.8927 | Positive treatment effect |
| Day 12 | 6.8647 | Positive treatment effect |
| Day 13 | 7.9675 | Positive treatment effect |
| Day 14 | 6.5146 | Positive treatment effect |

*Negative treatment effect happened because of the average height of 'Choy Sam' which watered by electric fields treated water are lower than without electric fields treated water.

The result of independence test is shown in Table 14 and Table 15. The analysis conditions of the collected data are as follows:

1. Significance level = $\alpha = 5\%$
2. H_0 : the height of 'Choy Sam' and watered with/without electric fields treated water are independent
3. H_1 : the height of 'Choy Sam' and watered with/without electric fields treated water are dependent
4. Reject H_0 if $X^2 > X_{\alpha, (r-1)(c-1)}^2 = X_{0.005, 1}^2 = 3.841$

Table 14. The number of plants that the heights of stem are less than 90mm or exceeding 90mm

| Condition | Height of stems | |
|----------------------------------|-----------------|--------|
| | <90 mm | ≥90 mm |
| Exposed to electric fields | 31 | 19 |
| Do not expose to electric fields | 40 | 10 |

Table 15. The value of The value of O_{ij}, E_{ij}, X^2

| O_{ij} | E_{ij} | $\frac{(O_{ij} - E_{ij})^2}{E_{ij}}$ |
|----------|----------|--------------------------------------|
| 31 | 35.5000 | 0.5704 |
| 19 | 14.5000 | 1.3966 |
| 40 | 35.5000 | 0.5704 |
| 10 | 14.5000 | 1.3966 |
| X^2 | | 3.9340 |

Since $X^2 > 3.841$, so we reject H_0 and conclude that the height of stems is dependent on watered with/without electric fields treated water.

Secondly, the percentage of germination and growth rate of bean sprout is observed. For the percentage of germination, the result is shown in Table 16.

Table 16. The percentage of germination for bean sprouts that watered with/without electric fields treated water

| Time | Percentage of germination with electric fields (%) | Percentage of germination without electric fields (%) |
|-------|--|---|
| Day 1 | 0 | 0 |
| Day 2 | 75 | 65.0 |
| Day 3 | 92.5 | 90.0 |
| Day 4 | 92.5 | 90.0 |
| Day 5 | 92.5 | 90.0 |
| Day 6 | 92.5 | 90.0 |

For the growth rate, the result of hypothesis test involving differences of two population means, $\mu_1 - \mu_2$ ($n_1 < 30, n_2 < 30$) is shown as table 17. 20 highest plants were chosen in this method.

The analysis conditions of the collected data are as follows:

1. $n_1 = n_2 = 20$
2. Significance level = $\alpha = 5\%$
3. Null hypothesis is $H_0 : \mu_1 = \mu_2$
4. Alternative hypothesis is $H_1 : \mu_1 > \mu_2$
5. Reject H_0 if $t_{\text{test}} > t_{\alpha, v} \approx 1.69$

Table 17. Mean, standard deviation and t-value of the height of the stem

| Time | Mean(mm) | | Standard Deviation(mm) | | t _{test} Value | Result |
|-------|----------|--------------|------------------------|--------------|-------------------------|-----------------|
| | E-fields | Non E-fields | E-fields | Non E-fields | | |
| Day 1 | 0 | 0 | 0 | 0 | 0 | $\mu_1 = \mu_2$ |
| Day 2 | 2.25 | 1.40 | 0.63 | 0.59 | 4.43 | $\mu_1 > \mu_2$ |
| Day 3 | 5.70 | 4.45 | 1.58 | 1.31 | 2.82 | $\mu_1 > \mu_2$ |
| Day 4 | 19.05 | 16.40 | 6.42 | 7.01 | 1.24 | $\mu_1 = \mu_2$ |
| Day 5 | 79.05 | 62.05 | 26.14 | 29.63 | 1.92 | $\mu_1 > \mu_2$ |
| Day 6 | 100.5 | 84.40 | 25.11 | 33.89 | 1.70 | $\mu_1 > \mu_2$ |

The result of F-test in ANOVA is shown in Table 18. 20 highest plants were chosen in this method. The analysis conditions of the collected data are as follows:

1. $n_i = n_k = 20$
2. $N=40, k=2$
3. Significance level = $\alpha = 5\%$
4. $H_0: \alpha_1 = \alpha_2 = 0$ Versus $H_1: \alpha_i \neq 0$
5. Reject H_0 if f value $> f_{\alpha; k-1, N-k} = f_{0.05; 1, 38} = 4.1247$

Where α_i is the i -th treatment effect.

Table 18. The result of F-test in ANOVA

| Time | f Value | Result |
|-------|---------|---------------------------|
| Day 1 | 0 | No treatment effect |
| Day 2 | 18.8694 | Positive treatment effect |
| Day 3 | 7.9579 | Positive treatment effect |
| Day 4 | 1.5517 | No treatment effect |
| Day 5 | 3.70065 | No treatment effect |
| Day 6 | 2.9132 | No treatment effect |

The result of independence test is shown in Table 19 and Table 20. The analysis conditions of the collected data are as follows:

1. Significance level = $\alpha = 5\%$
2. H_0 : the height of bean sprout and watered with/without electric fields treated water are independent
3. H_1 : the height of bean sprout and watered with/without electric fields treated water are independent
4. Reject H_0 if $X^2 > X^2_{\alpha, (r-1)(c-1)} = X^2_{0.005, 1} = 3.841$

Table 19. The number of plants that the heights of stem are less than 100mm or exceeding 100mm

| Condition | Height of stems | |
|----------------------------------|-----------------|---------|
| | <100 mm | ≥100 mm |
| Exposed to electric fields | 28 | 12 |
| Do not expose to electric fields | 33 | 7 |

Table 20. The value of O_{ij}, E_{ij}, X^2

| O_{ij} | E_{ij} | $\frac{(O_{ij} - E_{ij})^2}{E_{ij}}$ |
|----------|----------|--------------------------------------|
| 28 | 30.5000 | 0.2049 |
| 12 | 9.5000 | 0.6579 |
| 33 | 30.5000 | 0.2049 |
| 7 | 9.5000 | 0.6579 |
| X^2 | | 1.7256 |

Since $X^2 < 3.841$, so we accept H_0 and conclude that the height of stems is independent on watered with/without electric fields treated water.

4. Analysis

Figure 1 and 2 show the comparison between the height of stem of 'Choy Sam' and bean sprouts with and without electric fields respectively. The heights of the stem for both young vegetables that are exposed to electric fields are higher than those without electric fields.

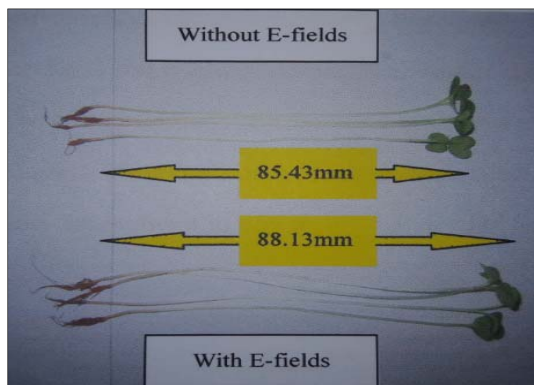


Figure 1. Comparison of the average height of 'Choy Sam' between with and without electric fields after two weeks

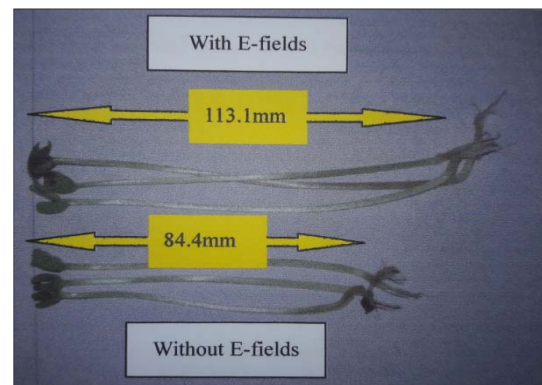


Figure 2. Comparison of the average height of bean sprouts between with and without electric fields after one week

Figure 3 and Figure 4 show the comparison of the height of stem for 'Choy Sam' and bean sprouts between with and without electric fields treated water respectively. The heights of the stem for both young vegetables that are watered with electric fields treated water were higher than those without electric fields treated water thereby elucidating the effect of electric field treated water towards the growth of the both young vegetables.

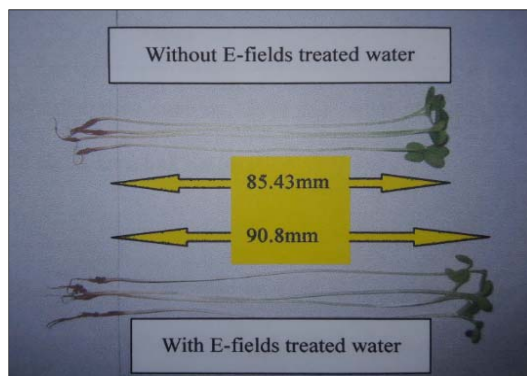


Figure 3. Comparison of the average height of 'Choy Sam' between with and without electric fields treated water after two weeks

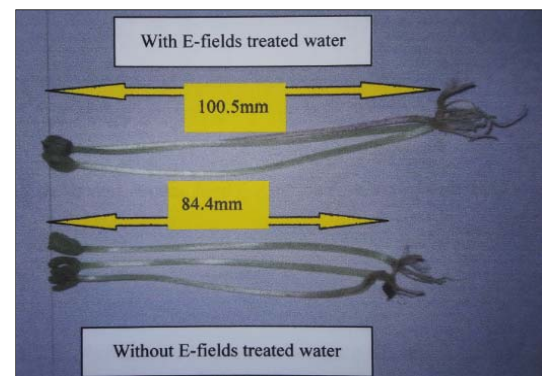


Figure 4. Comparison of the average height of bean sprouts between with and without electric fields treated water after one week

Figure 5 and Figure 6 show the percentage of germination for 'Choy Sam' and bean sprouts that exposed/did not expose to electric fields respectively. For Figure 5 on the day 2, the percentage of germination with electric fields was 20% more than without electric fields. From day 5 to day 14, the percentages of germination with/without electric fields were 76% and 74%

respectively. For Figure 6 on the day two the percentage of germination with electric fields was 17.5% more than without electric fields. From the day 3 to day 6, the percentages of germination with/without electric fields were 95% and 90% respectively.

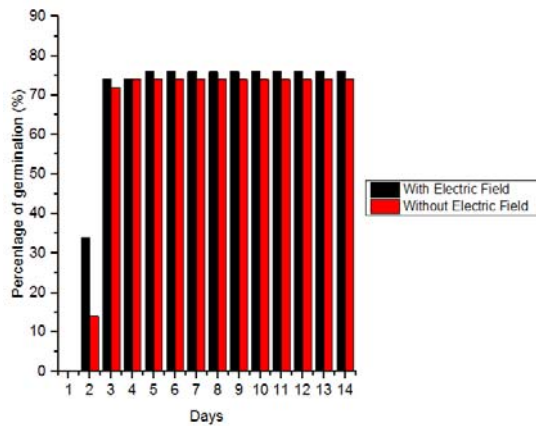


Figure 5. The germination rate vs. Days for 'Choy Sam' which exposed/do not expose to electric fields

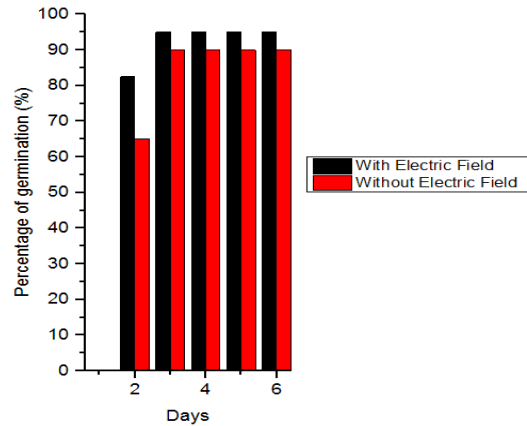


Figure 6. The germination rate vs. Days for near sprouts that exposed/do not expose to electric fields

Figure 7 and Figure 8 show the arithmetic average height of stems and standard deviation for 'Choy Sam' and bean sprouts that exposed/do not expose to electric fields respectively. From the Figure 7 on the day 14, the average height was equal to 88.13 mm and the standard deviation was equal to 8.04 mm but without electric fields equal to 85.43 mm and 8.65 mm respectively. Besides that, the slope of the average height of stems for with and without electric fields was increased rapidly from day 1 to day 8 and increase gradually after day 8. The growing rates of 'Choy Sam' with and without electric fields have nearly the same rate of height for the first eight days. However, the growth of 'Choy Sam' with electric fields starts to increase from day 9 to day 14. From Figure 8, on the day 6, the average height was equal to 113.10 mm and the standard deviation was equal to 25.24 mm but without electric fields was equal to 84.40 mm and 3.89 mm respectively.

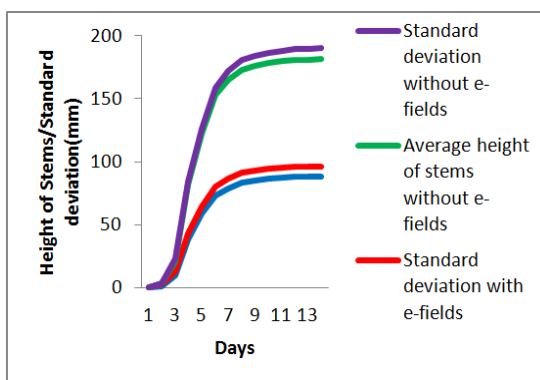


Figure 7. The height of stems and standard deviation vs. days for 'Choy Sam' which exposed/do not exposed to electric fields

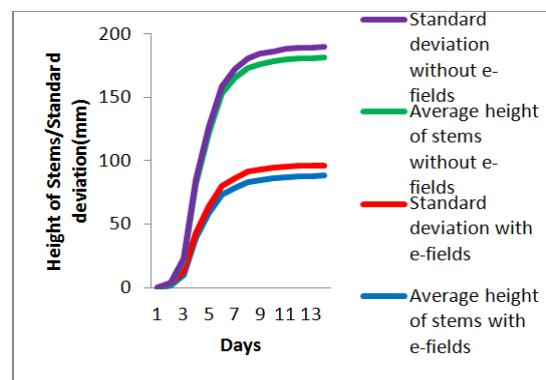


Figure 8. The height of stems and standard deviation vs. Days for bean sprout that exposed/do not expose to electric fields

Moreover, the slope of the average height of stems for with and without electric fields was increased steadily from day 1 to day 3 and increased speedily after three days but it was a

maximum slope on the day 5. The growing rates of bean sprouts with and without electric fields have nearly the same rate of height for the first three days. However, the growth of bean sprouts with electric fields starts to increase rapidly from day 4 to day 6.

Figure 9 and Figure 10 show the percentage of germination for 'Choy Sam' and bean sprouts that watered with/without electric fields treated water respectively. For Figure 9 on the day 2, the percentage of germination with electric fields treated water was 2% more than without electric fields treated water. However, from day 4 to day 14, the percentages of germination without electric fields treated water are 4% more than with electric fields treated water. For Figure 10 on the day 2, the percentage of germination with electric fields treated water was 10% more than without electric fields treated water. From day 3 to day 6, the percentages of germination with/without electric fields treated water were 92.5% and 90% respectively.

Figure 11 and Figure 12 show the arithmetic average height of stems and standard deviation for 'Choy Sam' and bean sprouts that watered with and without electric fields treated water respectively. From the Figure 11, on the day 14, the average height was equal to 90.80 mm and the standard deviation was equal to 7.61 mm but without electric fields treated water was equal to 85.43 mm and 8.65 mm respectively. Furthermore, the slope of the average height of stems for with and without electric fields treated water was increased rapidly from day 1 to day 7 and increase gradually after day 7. The growing rates of 'Choy Sam' with and without electric fields treated water have nearly the same rate of height for the first seven days. However, the growth of 'Choy Sam' with electric fields treated water starts to increase from day 8 to day 14.

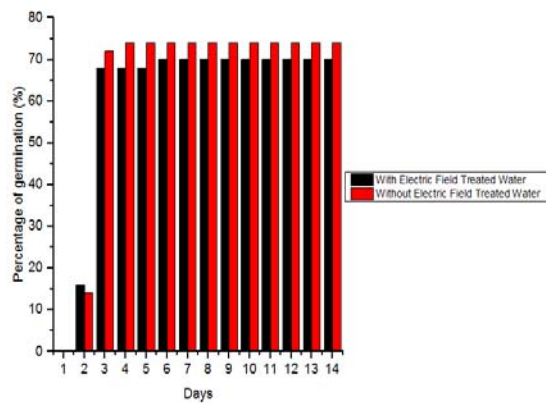


Figure 9. The germination rate vs. Days for 'Choy Sam' that watered with/without electric fields treated water

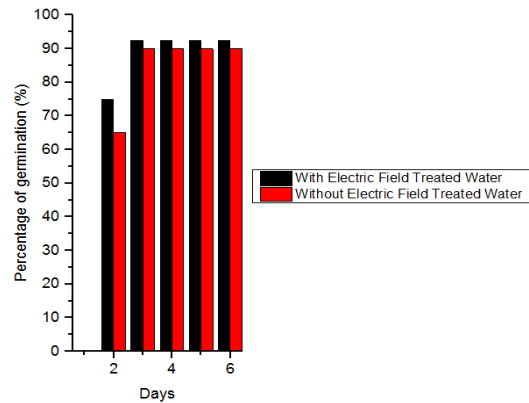


Figure 10. The germination rate vs. Days for bean sprouts that watered with/without electric fields treated water

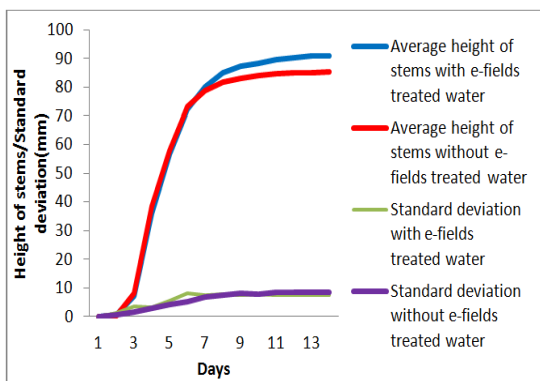


Figure 11. The height of stems and standard deviation vs. Days for 'Choy Sam' that watered with/without electric fields treated water

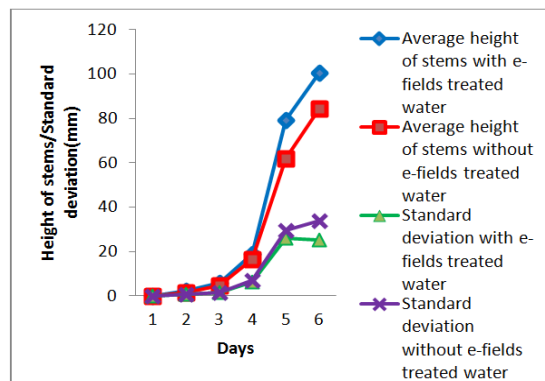


Figure 12. The height of stems and standard deviation vs. days for bean sprouts that watered with/without electric fields treated water

From the Figure 12 on the day 6, the average height was equal to 100.50 mm and the standard deviation was equal to 25.12 mm but without electric fields treated water was equal 84.40 mm and 33.89 mm respectively. Apart from that, the slope of average height of stems for with and without electric fields treated water was increased gradually from day 1 to day 3 and increased rapidly after day 3, but it was maximum slope on the day 5. The growing rates of bean sprouts with and without electric fields treated water have nearly the same rate of height for the first four days. However, the growth of bean sprouts with electric fields treated water starts to increase speedily from day 5 to day 6.

Figure 13 shows the percentage of germination for 'Choy Sam' which exposed to electric fields and watered with electric fields treated water respectively. On the day 2, the percentage of germination for 'Choy Sam' which exposed to electric fields was 18% more than those watered with electric fields treated water. However, from day 4 to day 14, the percentages of germination that exposed to electric fields were 6% more than with electric fields treated water. Figure 14 shows the comparison between the maximum heights of stems for 'Choy Sam' which exposed to electric fields and watered with electric fields treated water. From day two until day five, the maximum height of stems that exposed to electric fields was greater than the maximum height of stems that watered with electric fields treated water. However, the heights of these plants that watered with electric fields treated water were higher than those exposures with electric fields from day six until day 14. It means that that effect of electric fields treated water towards the growth of 'Choy Sam' was greater than the exposure to electric fields.

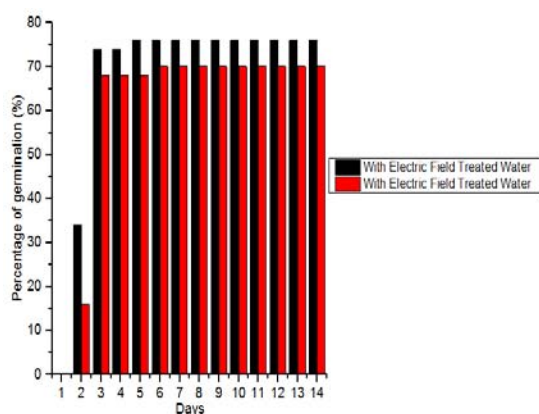


Figure 13. The germination rate vs. Days for 'Choy Sam' that exposed to electric fields and watered with electric fields treated water

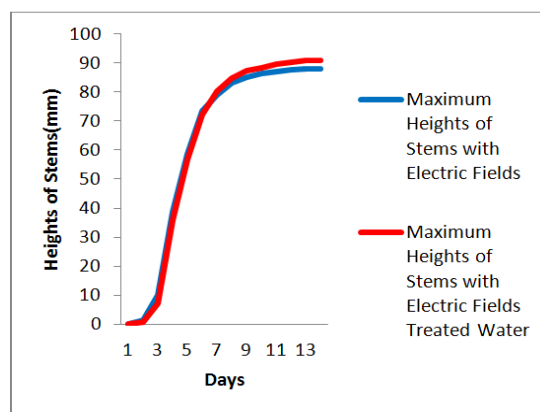


Figure 14. The height of stems vs. days for 'Choy Sam' which exposed to electric fields and watered with electric fields treated water

Figure 15 shows the percentage of germination for bean sprouts that exposed to electric fields and watered with electric fields treated water respectively. On the day 2, the percentage of germination for bean sprouts that exposed to electric fields was 7.5% more than those watered with electric fields treated water. However, from day 4 to day 14, the percentages of germination that exposed to electric fields were 2.5% more than with electric fields treated water.

Figure 16 shows the comparison between the maximum heights of stems for bean sprouts that exposed to electric fields and watered with electric fields treated water. From day two until day 6, the maximum height of stems that exposed to electric fields was greater than the maximum height of stems that watered with electric fields treated water. On the day 6, the maximum heights of stems that exposed with electric fields were 16 mm higher than those watered with electric fields treated water. It means that the effect of electric fields towards the growth of bean sprouts was greater than electric fields treated water.

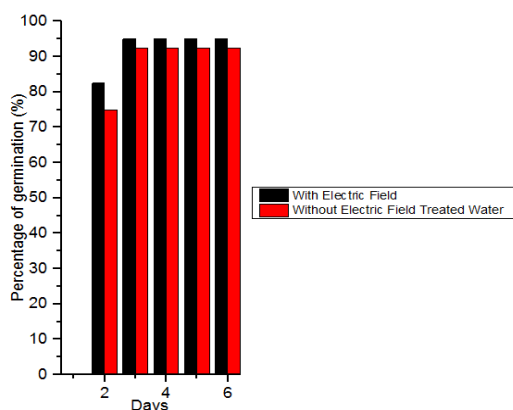


Figure 15. The germination rate vs. Days for bean sprouts that exposed to electric fields and watered with electric fields treated water

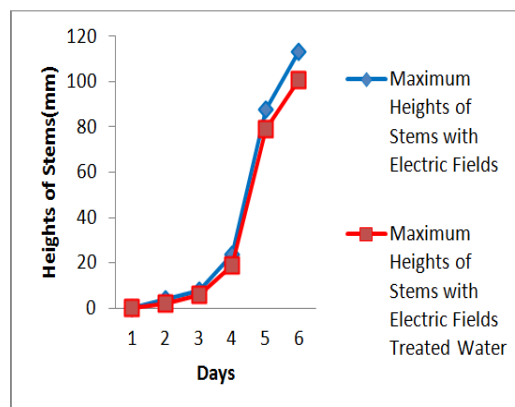


Figure 16. The height of stems vs. Days for bean sprouts that exposed to electric fields and watered with electric fields treated water

4. Conclusion

The percentage of germination and growth rate for both young vegetables has been considered in the experiment based on the statistical approach. These give more quantitative analysis of the effect of electric fields on the germination and growth rate of young vegetables. From these results, electric fields and electric fields treated water influenced the germination rate and height of stems for both young vegetables. The height of stems in with electric fields and electric fields treated water are higher and longer than of those without electric fields and electric fields treated water. Last but not least, it is clear that vast track of land along the transmission lines right-of-way is not utilized for the useful purpose. This is because of the hazardous of electric and magnetic fields towards humans. Based on the regulation made by the government, the land located nearby the transmission cannot be built in a residential suburb. As a result, this experiment leads to the possibility of cultivates vegetables in those places. From the positive results as shown in this research concerted and organized farming of vegetable utilizing power lines right-of-way should be undertaken.

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