

## Exposure of guar seeds (*C. Tetragonoloba* L.) to electric field

Bara'ah Ali El-Tahir<sup>1</sup>, Sayadat El-Tigani Mohamed<sup>2</sup>

<sup>1</sup> Assistant Professor, Scientific Department, Faculty of Education, University of the Holly Quran and Islamic Sciences, Khartoum, Sudan

<sup>2</sup> Professor of Plant Physiology, Department of Botany, Faculty of Science, University of Khartoum, Khartoum, Sudan

### Abstract

This experiment was designed to investigate the effect of electric field on treated seeds of five genotypes of guar (*C. Tetragonoloba* L. plant) Gm2, Gm5, Gm6, Gm8 and Gm34, and know if this treatment is efficient to affect its growth and development. This effect is expressed in terms of electric energy density created within pairs of copper plates forming electric capacitors in a DC current circuit connected to an electric source. The system used was with two copper plate's and four voltage levels (0, 6, 12, and 18) volts. Seeds of guar were located within spaces between each capacitor's plates and are exerted upon by different energy densities. The obtained data were statistically analyzed. The results showed that the applied electric fields affected guar growth and development as shown in morphological characters (plant height, number of leaves, stem diameter, number of nodes, number of branches, number of flowers) and moisture content.

**Keywords:** *C. tetragonoloba*-guar-electric field- exposure- stem diameter

### 1. Introduction

The effect of electric field on crop plant growth have been studied by many scientists (Briggs *et al.*, 1926<sup>[2]</sup>; Collins *et al.*, 1929<sup>[3]</sup>; Krueger *et al.*, 1965<sup>[11]</sup>; Kotaka and Krueger, 1967<sup>[9]</sup>; Kotaka *et al.*, 1968<sup>[10]</sup> and Krueger *et al.*, 1978<sup>[12]</sup>). Yuji *et al.* (2006)<sup>[18]</sup> had studied the effect of electric field on plant growth. In their study, they proved that the DC electric field accelerated the growth rate of the plant, and the change of the growth rate depends on the time zone of the DC electric field application. Wheaton (1968)<sup>[17]</sup> found that treatment in an electric field affected the germination rate of corn and soybeans. Also, increasing the electric field intensity caused the mean time for 50 percent of the seeds to germinate when working with air dry corn or soaked soybeans. Matheu and Stevenson (1990)<sup>[13]</sup> found that weak electric field has a stimulatory effect on germination of Waldo bean seeds. The average root length of the test groups was significantly greater than that of the control groups. Additional experiments suggested that the rate of the growth of the plants in soil was enhanced by applying a weak electric field to the soil. Okumura *et al.* (2010)<sup>[15]</sup> had studied the influence of D.C. electric field on *Raphanus sativus longipinnatus* and *Arabidopsis thaliana*. They found that electric field improved the seed germination rate in the two plants. Also, electric field increased the length and weight of *Raphanus*, where enhanced the utilization of substances which are stored in the seed of *Raphanus*. In another study Costanzo (2008)<sup>[4]</sup> has studied the effect of electric fields on the growth of soy seedlings. Her results showed that no significant change in the length of the seedling was produced by an electrostatic field of 3600 V/m. On the other hand, AC electric fields of 3600 and 1800 V/m increased the average length of the seedlings by about 12% and 8% respectively. Costanzo

(2008)<sup>[4]</sup> suggested that plant growth can be influenced by using very low-frequency electric fields although the underlying biophysical mechanism is still unclear. According to Karez and Burdach (1995)<sup>[8]</sup> the electric field (15V) caused inhibition of the elongation growth of intact seedlings which was dependent on both the polarity and the duration of the applied voltage. The growth inhibition was greater when the tip of the shoot was positive relative to the roots. Rezaei-Zarchi *et al.* (2012)<sup>[16]</sup> were examined the effect of electric field on growth of alfalfa seeds (*Medicago sativa*). They tested four voltages (1, 3, 5 and 7) volts for time 1 (t1=2.5 hrs.) and time 2 (t2= 5hrs.). The results showed that the maximum germination was achieved by the treatment of V4t1 and V3t2. The highest and lowest root was in V4t1 and control group respectively. The electric field effectively impact on root length and most effective treatment was V4t1.

Another study of Molamofrad *et al.* (2013)<sup>[14]</sup> studied the effect of electric field on seedlings height of onion seed, for AzarShahr variety. The onion seeds were exposed to the electric fields of 2, 4, 9 and 14kV. Their results showed that the maximum increase in seedling height was attained after treatment with 9 kV.

### 2. Materials and methods

#### 2.1.1. Plant materials

Mature seeds of five genotypes of guar (Gm<sub>2</sub>, Gm<sub>5</sub>, Gm<sub>6</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>) were provided by Dr. Abdel Wahab Hassan Abdalla, Department of Agronomy, Faculty of Agriculture, University of Khartoum. Harvest of January, 2014

#### 2.1.2. Source of electric field

In this study electrical supply system were used as source of electric field. This was designed by El-Tahir (2011)<sup>[5]</sup> with some modifications.

### 2.1.2.1. Experimental Set-Up

The system was connected with 25cm<sup>2</sup> and voltages level was either 0, 6, 12 or 18 V.

## 2.2. Methods

### 2.2.1.1. Germination of seeds in the field

The general procedure for seed germination can be summarized as follows: guar seeds were selected carefully from each genotype and soaked in tap-water for 3-4 hrs. Then seeds were planted in black polythene bags (30x50 cm) containing a soil mixture of sand and clay at a ratio of 1:1, (v/v). The germinating seeds were supplied with sufficient water during the experimental period.

#### 2.2.1.1.1. Growth measurements

For plant growth experiment the following parameters were recorded: plant height, number of leaves and stem diameter were recorded weekly during the experimental period. The number of branches, number of nodes, number of flowers were recorded after the vegetative stage.

#### 2.2.1.1.2. Moisture content

The moisture content of the sample was determined according to the procedure of A.O.A.C. (2000) [1]. Two grams of the sample were weighed in an empty, dry and clean crucible with a known weight. The crucible containing the sample was then placed in an oven at 105°C for 24 hrs. After that, the crucible was removed and weighed three times at intervals until a constant weight was achieved. The average weight was calculated. The moisture content as percentage was calculated according to the equation:

$$\text{Moisture content (\%)} = \frac{w_1 - w_2}{S} \times 100$$

Where,  $w_1$  = weight of crucible and sample before drying  
 $w_2$  = weight of crucible and sample after drying  
 $S$  = original weight of the sample.

### 2.2.2. Treatment of seeds with electric field

Imbibed seeds or young plants of the five genotypes of guar were subjected to different doses of electric field.

#### Method of treatment

Genotypes used were Gm<sub>2</sub>, Gm<sub>5</sub>, Gm<sub>6</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>. In this experiment four treatments were used according to El-Tahir (2017) [6] during 24 hrs. The experiment duration was 112 days (15 weeks) after germination.

#### Seed germination

Forty seeds of each genotype of guar were selected carefully and soaked in tap-water for 3-4 hrs. Five imbibed seeds of each genotype of guar were germinated in a Petri-dish contained moistened filter paper.

#### Seed treatment

The Petri-dishes were set in the gaps between the plates of the capacitors. The electric circuit was switched on. After 24hrs germinating seeds were planted in black polythene bags (30x50cm) containing a soil mixture of sand and clay at the ratio of 1:1, v/v and supplied with sufficient water. One experimental set of each genotype was isolated from any electric field and kept as a control. Germination percentage was calculated. Plant height, number of leaves, stem diameter were recorded weekly during 15 weeks after treatment, while number of branches, nodes, flowers and fruits was recorded after vegetative stage. Also, moisture content was calculated at the end of the experiment.

### 2.2.3. Statistical analysis

The collected data were subjected to descriptive statistical analysis, where means and standard deviations were estimated using the procedure described by Gomez and Gomez (1984) [7].

## 3. Results and discussion

### 3.5.1. Plant height

Results presented in Table 1 a (1<sup>st</sup> week) show that all treatments reduced plant height of the five genotypes when compared with control plants. Twelve volts had the highest mean value of reduction. It significantly reduced plant height of genotypes Gm<sub>2</sub>, Gm<sub>5</sub> and Gm<sub>6</sub>, while 12 volts were not significant for plant height of genotypes Gm<sub>8</sub> and Gm<sub>34</sub>. Six volts significantly reduced plant height of genotypes Gm<sub>2</sub>, Gm<sub>6</sub> and Gm<sub>8</sub>, and 18 volts significantly reduced plant height of genotypes Gm<sub>6</sub> and Gm<sub>34</sub>. Table 1 a (2<sup>nd</sup> week) shows that the same pattern of stem elongation was observed. Twelve volts treatment significantly reduced plant height of genotypes Gm<sub>2</sub>, Gm<sub>5</sub>, Gm<sub>6</sub> and Gm<sub>8</sub>. The highest percentage of reduction by 12 volts was 45.1% in genotype Gm<sub>2</sub>. Six volts significantly reduced plant height of genotypes Gm<sub>6</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>, while 18 volts significantly reduced plant height of genotypes Gm<sub>6</sub> and Gm<sub>8</sub>. Results presented in Table 1 a (3<sup>rd</sup> week) show that all treatments reduced plant height of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction. It significantly reduced plant height of genotypes Gm<sub>2</sub> and Gm<sub>6</sub>, but not significantly reduced plant height of genotypes Gm<sub>5</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>. Also 12 volts significantly reduced plant height of genotypes Gm<sub>2</sub> and Gm<sub>5</sub>, while 6 volts significantly enhanced plant height of genotypes Gm<sub>5</sub> and Gm<sub>34</sub>. The results shown in Table 1 b (4<sup>th</sup> week) reveal that 6 volts increased plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm<sub>5</sub> (69.9%) and genotype Gm<sub>34</sub> (20.8 %), while 12 and 18 volts treatments decreased plant height of the five genotypes when compared with control plants.

Twelve volts significantly reduced plant height of genotype Gm<sub>2</sub> (26.9%), and 18 volts significantly reduced plant height of genotype Gm<sub>6</sub> (39.1%).

**Table 1a:** Plant height (cm) of guar genotypes 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> weeks after treatments.

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	1 <sup>st</sup> week (13.8.2015)						
0 volt (control)	5.4 (100%)	4.4(100%)	5.9(100%)	5.1(100%)	5.1(100%)	5.2	0.5
6 volts	3.464%	490.4%	3.72.7%	4.486.3%	5.3103.5%	4.2	0.7
12 volts	2.444.3%	2.965.5%	4.373.5%	4.995.1	5.4106%	3.9	1.3
18 volts	4.481.7%	4.7105.1%	4.373.5%	4.894.1%	4.791.8%	4.6	0.2

MEAN ± SD	3.9± 1.3	4.0± 0.8	4.4 ± 1.0	4.8± 0.3	5.1 ± 0.3		
2 <sup>nd</sup> week (20.8.2015)							
0 volt (control)	6.8(100%)	6(100%)	7.1(100%)	6.8(100%)	6.5(100%)	6.6	0.4
6 volts	6.697.5%	6.2102.8%	5.374.4%	5.783.6%	6.9105.5%	6.1	0.7
12 volts	3.754.9%	5.388.3%	5.273.5%	6.190%	6.497.5%	5.3	1.0
18 volts	5.986.8%	5.692.9%	3.548.8%	6.291.4%	6.396.7%	5.5	1.2
MEAN±SD	5.8 ± 1.4	5.8 ± 0.4	5.2 ± 1.5	6.2 ± 0.5	6.5 ± 0.3		
3 <sup>rd</sup> week (27.8.2015)							
0 volt (control)	7.2(100%)	6.3(100%)	7.4(100%)	7.2(100%)	7.1(100%)	7.0	0.4
6 volts	7.199.4%	7112%	6.182.4%	6.286.6%	7.7107.7%	6.8	0.6
12 volts	5.273.1%	5.689.6%	7.4100%	6.590.6%	6.997.2%	6.3	0.9
18 volts	6.286.3%	5.791.6%	4.6562.8%	6.692%	6.997.2%	6.0	0.9
MEAN±SD	6.4 ± 0.9	6.1±0.6	6.4±1.3	5.0±3.4	7.1±0.4		

Results in Table 1 b (5<sup>th</sup> week) show that 6 volts enhanced plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (61.7%) and Gm34 (31.9%), while 6 volts significantly decreased plant height of Gm8 by 28%. Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction. It significantly decreased plant height of genotypes Gm6

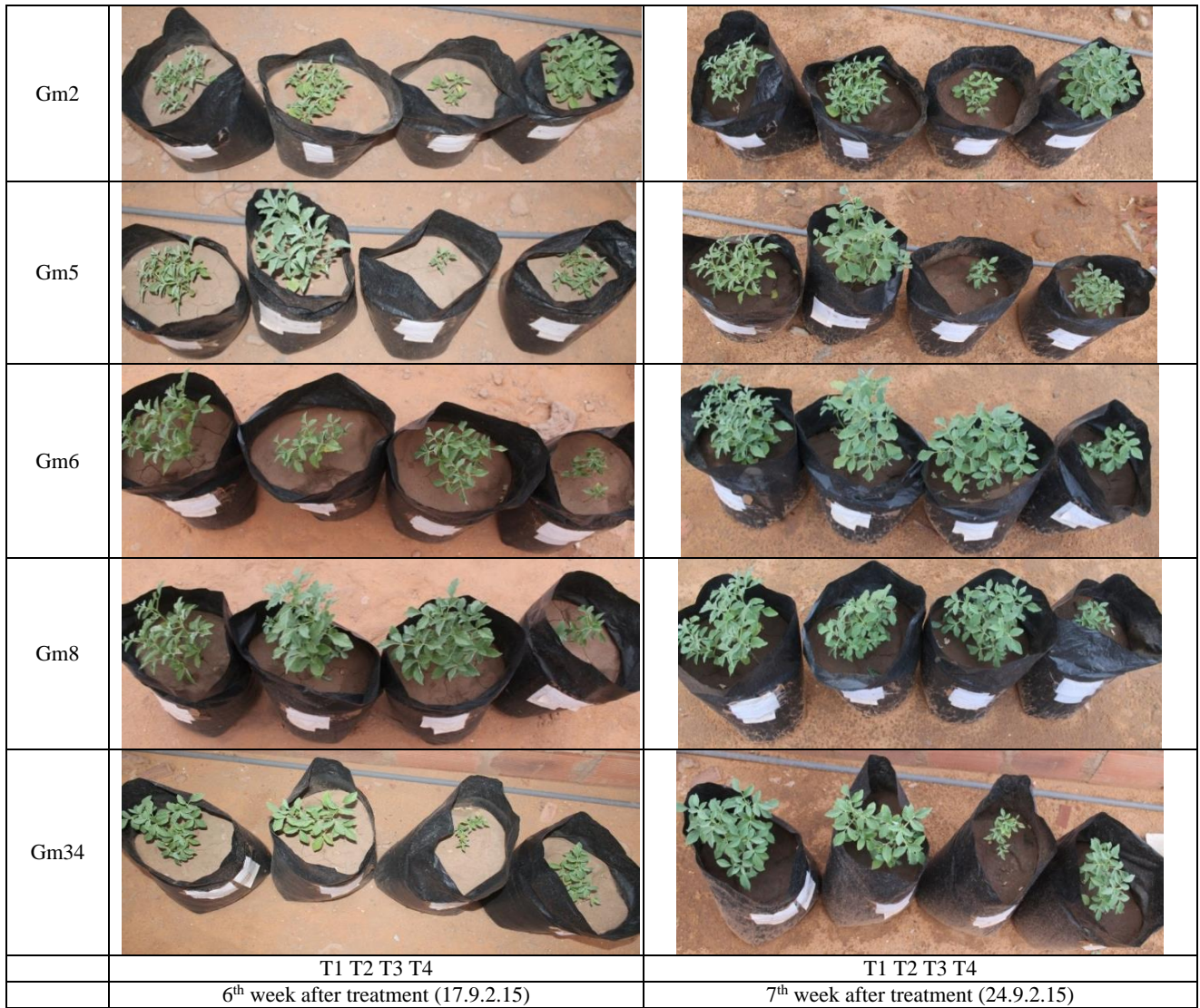
(45.2%) and Gm8 (45.3%), while 18 volts significantly enhanced plant height of genotype Gm2 by 34.5%. Results in Table 1 b (6<sup>th</sup> week) show that 6 volts enhanced plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (69.9%) and Gm6 (36%). Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction.

**Table 1:** b: Plant height (cm) of guar genotypes 4<sup>th</sup>, 5<sup>th</sup> week and 6<sup>th</sup> week after treatments

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
4 <sup>th</sup> week (3.9.2015)							
0 volt (control)	8.5(100%)	7.6 (100%)	10.4 (100%)	8.9 (100%)	8.2 (100%)	8.7	1.0
6 volts	7.8 91.6%	12.9 169.9%	13.1 126.2%	7.5 84.3%	10.0 120.8%	10.2	2.7
12 volts	6.2 73.1%	6 79.2%	9.6 92.4%	8.4 94.1%	7.4 89.2%	7.5	1.5
18 volts	9.5 111.8%	6.3 83.5%	6.3 60.9%	7.2 80.3%	7.5 90.7%	7.3	1.3
MEAN±SD	8.0 ± 1.4	8.2 ± 3.2	9.8 ± 2.8	9.8 ± 2.8	8.3 ± 1.2		
5 <sup>th</sup> week (10.9.2015)							
0 volt (control)	10.8 (100%)	11.9 (100%)	16.1 (100%)	14.2 (100%)	11.3 (100%)	12.9	2.2
6 volts	10.8 100.5%	19.2 161.7%	19.5 121.5%	10.2 72%	14.9 131.9%	14.9	4.4
12 volts	6.9 63.7%	7.7 65%	16.2 101.1%	12 82.2%	7.9 69.4%	10.1	3.9
18 volts	14.5 134.5%	8.0 67.1%	8.8 54.8%	7.8 54.7%	9.0 79.4%	9.6	2.8
MEAN±SD	10.7 ± 3.1	11.7 ± 5.3	15.1 ± 4.5	11.0 ± 2.7	10.8 ± 3.1		
6 <sup>th</sup> week (17.9.2015)							
0 volt (control)	12.5 (100%)	15.0 (100%)	18.6 (100%)	17.7 (100%)	15.4 (100%)	15.9	2.4
6 volts	11.7 92.9%	25.4 169.9%	25.3 136%	13.8 78.3%	18 116.7%	18.8	6.4
12 volts	7.0 56.1%	8.1 54.2%	21.2 113.6%	15.5 87.9%	7.9 50.9%	11.9	6.2
18 volts	18.7 149.4%	10.0 67.1%	11.6 62.3%	8 45.3%	10.2 66.1%	11.7	4.1
MEAN±SD	12.5 ± 4.8	14.6 ± 7.7	19.2 ± 5.8	13.8 ± 4.1	12.9 ± 4.7		

It significantly decreased plant height of genotypes Gm6 (37.7%), Gm8 (54.7%) and Gm34 (33.9%), while 18 volts significantly enhanced plant height of genotype Gm2 by 49.4%. Results in Table 1 c (7<sup>th</sup> week) show that 6 volts increased plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (74.6%) and Gm6 (23.6%). Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Twelve volts significantly decreased plant height of genotypes Gm2 (31.9%) and Gm34 (57.9%). Also, 18 volts significantly decreased plant height of genotype Gm8 by 51.7%, but 18 volts significantly enhanced plant height of genotype Gm2 by 42.5%. Results of growing plants in 6<sup>th</sup> and 7<sup>th</sup> week were shown in Fig. 1. Results in Table 1 c (8<sup>th</sup> week) show that 6 volts increased plant height of the five genotypes. It

significantly enhanced plant height of genotypes Gm5 (62%) and Gm6 (34.8%). Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction. It significantly decreased plant height of genotype Gm8 by 32.4%, while 18 volts significantly enhanced plant height of genotype Gm2 by 34.2%. Results in Table 1 c (9<sup>th</sup> week) show that 6 volts increased plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (82.4%) and Gm6 (20.2%). Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Treatment with 18 volts had the highest mean value of reduction. It significantly decreased plant height of

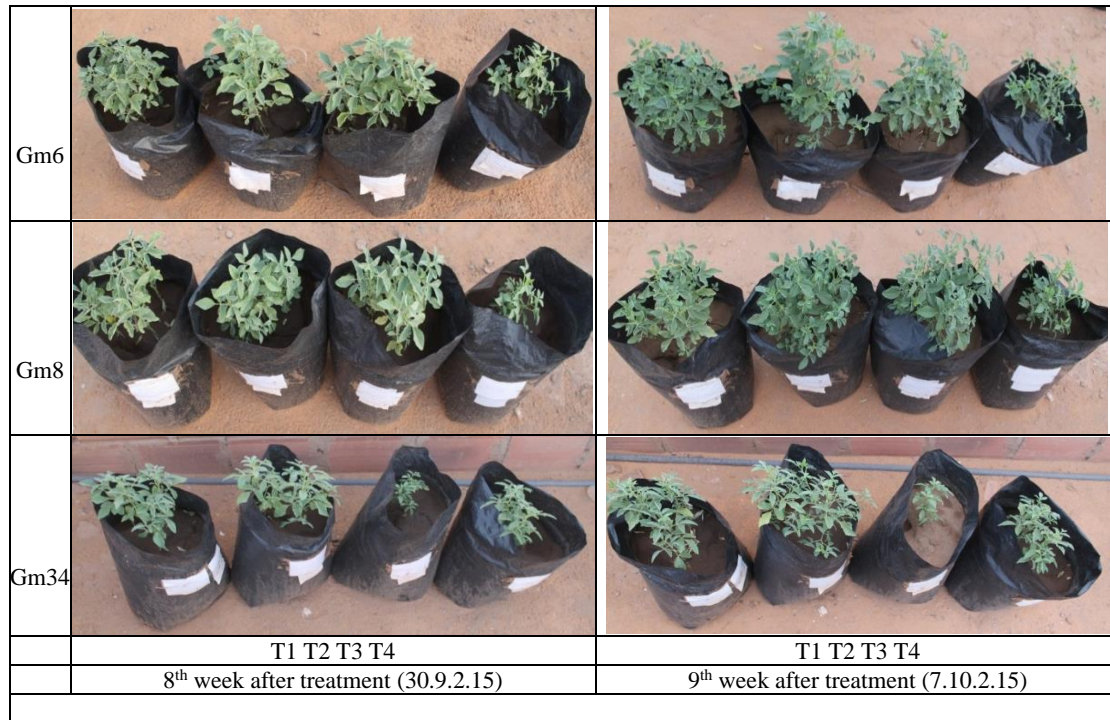


**Fig 1:** guar genotypes exposed to electric field throughout each growth stage 6<sup>th</sup> and 7<sup>th</sup> week after treatment T1= 0 volt (control), T2= 6 volts, T3= 12 volts, T4= 18 volts.

genotypes Gm6 (19.1%) and Gm8 (28.6%), while 18 volts significantly enhanced plant height of genotype Gm2 by 46%. Results of growing plants in 8<sup>th</sup> and 9<sup>th</sup> week were shown in Fig. 2. Results in Table 1 d (10<sup>th</sup> week) show that 6 volts increased plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (79%) and Gm6 (18.8%). Twelve and 18 volts decreased plant height of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction. It significantly decreased plant height of

genotypes Gm6 (13.9%) and Gm8 (20.9%), while 18 volts significantly enhanced plant height of genotype Gm2 by 38.6%. Results in Table 1 d (11<sup>th</sup> week) show that 6 volts increased plant height of the five genotypes. It significantly enhanced plant height of genotypes Gm5 (73%) and Gm6 (16.7%). Eighteen volts had the highest mean value of reduction. It significantly decreased plant height of genotypes Gm6 (14.9%) and Gm8 (20.4%), while 18 volts significantly enhanced plant height of





**Fig 2:** guar genotypes exposed to electric field throughout each growth stage 8<sup>th</sup> and 9<sup>th</sup> week after treatment T1= 0 volt (control), T2= 6 volts, T3= 12 volts, T4= 18 volts.

genotype Gm2 by 37.2%. Results of growing plants in 10<sup>th</sup> and 11<sup>th</sup> week were shown in Fig. 3. Results in Table 1 d (12<sup>th</sup> week) show that all treatments increased plant height of the five genotypes. Six volts had the highest mean value of increase. It significantly enhanced plant height of genotypes Gm5 (70.7%), Gm6 (19%) and Gm8 (7.1%).

Results of growing plants in 12<sup>th</sup> week were shown in Fig. 4. When varying values of voltages were employed, stem height increased with the increased voltage (range from 5.9 v up to 33.5 v). Voltages from 39.5 v to 81.5 v resulted in greater decrease in stem height (El-Tahir, 2011).

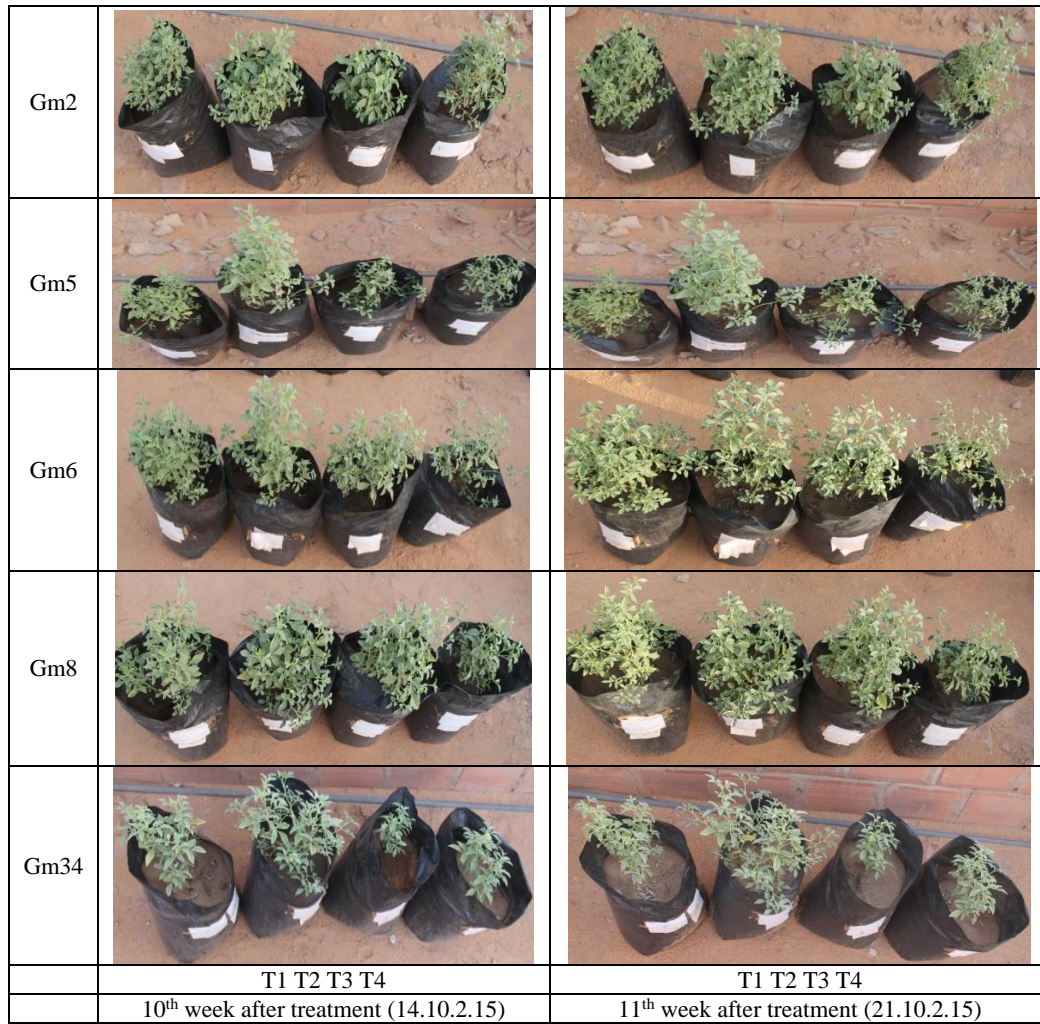
**Table 1c:** Plant height (cm) of guar genotypes 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> weeks after treatment

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
<b>Treatments</b>	<b>7<sup>th</sup> week (24.9.2015)</b>						
0 volt (control)	15.2 (100%)	17.1 (100%)	21.2 (100%)	20.9m (100%)	19.9 (100%)	18.9	2.6
6 volts	14.5 95.2%	29.8 174.6%	26.2 123.6%	18.7 89.5%	21.4 107.3%	22.1	6.0
12 volts	10.4 68.1%	12.1 71%	23.7 111.6%	21.4 102.5%	8.4 42.1%	15.2	6.9
18 volts	21.7 142.5%	13.0 76.1%	15.8 74.2%	10.1 48.3%	15.4 77%	15.2	4.3
MEAN±SD	15.4±4.7	18.0±8.2	21.7±4.5	17.7±5.2	16.3±5.8		
	<b>8<sup>th</sup> week (1.10.2015)</b>						
0 volt (control)	16.6 (100%)	18.5 (100%)	20.5 (100%)	20.4 (100%)	21.3 (100%)	19.4	1.9
6 volts	17.0 102.8%	30.0 162%	27.7 134.8%	20.7 101.6%	23.8 111.9%	23.8	5.2
12 volts	14.7 88.8%	16.6 89.7%	24.7 120.2%	23.7 116%	9.9 46.6%	17.9	6.2
18 volts	22.2 134.2%	15.0 80.9%	18.7 91.1%	13.8 67.6%	15.6 73.1%	17.0	3.4
MEAN±SD	17.6±3.2	20.0±6.8	22.9±4.0	19.6±4.2	17.6±6.2		
	<b>9<sup>th</sup> week (8.10.2015)</b>						
0 volt (control)	19.4 (100%)	20.0 (100%)	29.0 (100%)	25.6 (100%)	23.2 (100%)	23.4	4.0
6 volts	22.1 113.8%	36.4 182.4%	34.8 120.2%	26.6 104%	26.6 114.9%	29.3	6.1
12 volts	19.6 101.3%	19 95.1%	29.6 102.3%	29.4 114.8%	11.7 50.3%	21.9	7.7
18 volts	28.3 146%	18.9 94.6%	23.5 80.9%	18.3 71.4%	19.2 82.9%	21.6	4.3
MEAN±SD	22.3±4.2	23.6±8.6	29.2±4.7	25.0±4.7	20.2±6.4		

**4.5.2. Number of leaves**

Results in Table 2 a (1<sup>st</sup> week) show that all treatments reduced number of leaves of the five genotypes when compared with control plants. Twelve volts had the highest mean value of reduction. It significantly decreased number of leaves of genotypes Gm2, Gm5 and Gm6. Results in Table 2 a (2<sup>nd</sup> week) show that the same pattern observed.

Twelve volts significantly reduced number of leaves of genotypes Gm2 (55.6%) and Gm6 (40%). Results in Table 2 a (3<sup>rd</sup> week) show that all treatments reduced number of leaves of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction.



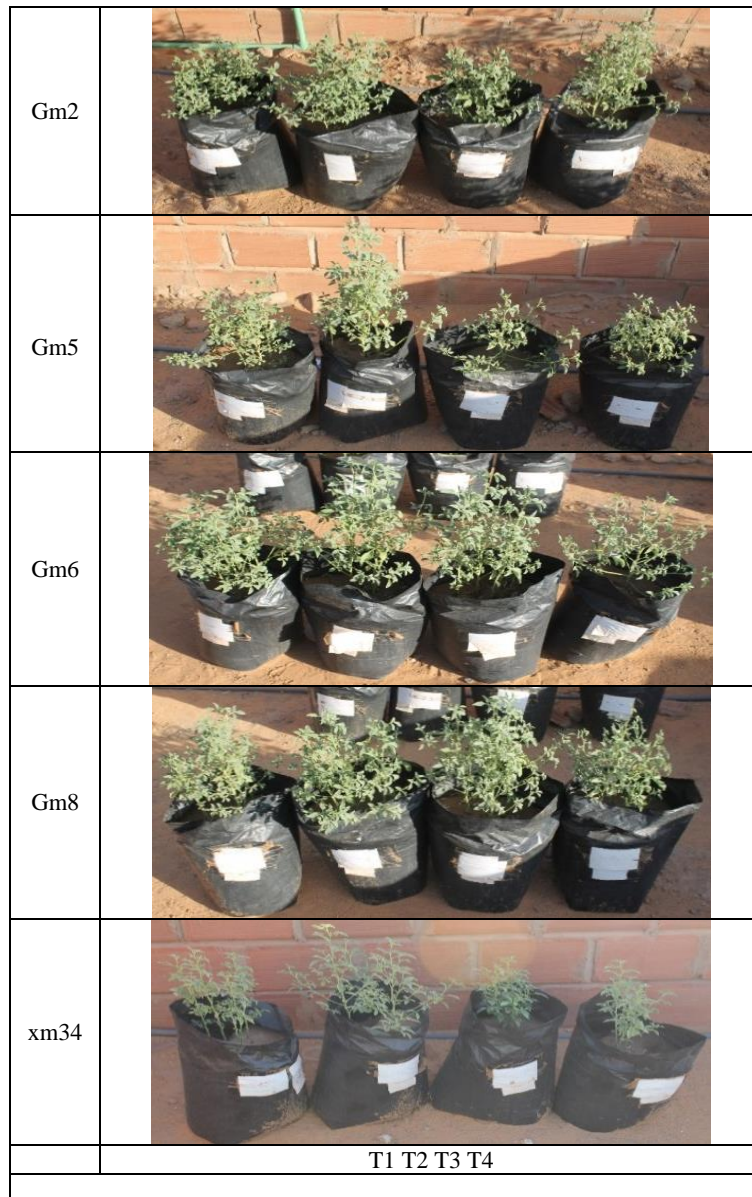
**Fig 3:** guar genotypes exposed to electric field throughout each growth stage 10<sup>th</sup> and 11<sup>th</sup> week after treatment T1= 0 volt (control), T2= 6 volts, T3= 12 volts, T4= 18 volts.

**Table 1 d:** Plant height (cm) of guar genotypes 10<sup>th</sup>, 11<sup>th</sup> and 12<sup>th</sup> weeks

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	10 <sup>th</sup> week (15.10.2015)						
0 volt (control)	22.5 (100%)	22.0 (100%)	31.4 (100%)	28.0 (100%)	25.0 (100%)	25.8	4.0
6 volts	25.3 112.8%	39.3 179%	37.3 118.8%	29.1 103.7%	29.3 116.8%	32.1	6.0
12 volts	23.7 105.5%	23.5 107.1%	33 105%	32.5 116.1%	13.7 54.7%	25.3	7.9
18 volts	31.1 138.6%	20.5 93.4%	27.1 86.1%	22.2 79.1%	20.4 81.5%	24.2	4.7
MEAN±SD	25.7±3.8	26.3±8.7	32.2±4.2	27.9±4.3	22.1±6.7		
	11 <sup>th</sup> week (22.10.2015)						
0 volt (control)	25.4 (100%)	25.3 (100%)	34.1 (100%)	31.3 (100%)	26.6 (100%)	28.5	4.0
6 volts	28.5 112.3%	43.7 173%	39.8 116.7%	32.0 102.1%	33.4 125.3	35.5	6.2
12 volts	27.2 107.1%	26.5 104.8%	35.9 105.3%	36.2 115.6%	17.1 64.1%	28.6	7.9
18 volts	34.8 137.2%	23.2 91.6%	29.1 85.1%	24.9 79.6%	22.5 86.4%	26.9	5.1
MEAN±SD	29.0±4.1	29.7±9.5	34.7±4.5	31.1±4.6	24.9±6.9		
	12 <sup>th</sup> week (29.10.2015)						
0 volt (control)	27.9 (100%)	27.1 (100%)	36.0 (100%)	32.4 (100%)	28.4 (100%)	30.4	3.8
6 volts	30.7 110.2%	46.3 170.7%	42.8 119%	34.7 107.1%	35.8 125.7%	38.1	6.3
12 volts	29.4 105.6%	29.1 107.3%	38.0 105.7%	38.5 118.7%	21.3 74.8%	31.3	7.2
18 volts	37.6 135%	25.5 93.8%	37 102.8%	27.3 84.2%	24.6 86.4%	30.4	6.4
MEAN±SD	31.4±4.3	32.0±9.7	38.5±3.0	33.2±4.7	27.5±6.2		

Is significantly reduced number of leaves of the genotypes Gm<sub>2</sub>, Gm<sub>5</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>. The highest percentage of reduction by 18 volts was (25%) in genotype Gm<sub>6</sub>, and the lowest one was 10% in genotype Gm<sub>34</sub>, while 18 volts significantly enhanced number of leaves of genotype Gm<sub>8</sub> by 9.4%. Results in Table 2 b (4<sup>th</sup> week) show that 12 and 18 volts decreased number of leaves of the five genotypes.

Eighteen volts had the highest mean value of reduction. It significantly reduced number of leaves of the genotypes Gm<sub>6</sub>, Gm<sub>8</sub> and Gm<sub>34</sub>. Also, 6 volts significantly reduced number of leaves of genotype Gm<sub>2</sub> by 13.6%. Results in Table 2 b (5<sup>th</sup> week) show that 12 and 18 volts decreased number of leaves of the five genotypes.



**Fig 4:** guar genotypes exposed to electric field throughout each growth stage, 12<sup>th</sup> week (28.10.2015) after treatment T1= 0 volt (control), T2= 6 volts, T3= 12 volts, T4= 18 volts.

**Table 2a:** Number of leaves of guar genotypes 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> weeks after treatment

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
<b>Treatments</b>	<b>1<sup>st</sup> week (13.8.2015)</b>						
0 volt (control)	1 (100%)	1 (100%)	1.3 (100%)	1 (100%)	1 (100%)	1.1	0.1
6 volts	0.6 57.1%	0.7 66.7%	0.7 53.3%	1 100%	0.7 66.7%	0.7	0.2
12 volts	0	0	0.3 24%	0.8 75%	1 100%	0.4	0.5
18 volts	1 100%	1 100%	1 100%	0.8 75%	0.8 75%	0.6	0.5
MEAN±SD	0.4±0.5	0.7±0.5	0.7±0.5	0.7±0.5	0.9±0.2		
	<b>2<sup>nd</sup> week (20.8.2015)</b>						
0 volt (control)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3	0
6 volts	2.8 94.4%	2 66.7%	3 100%	3 100%	3 100%	2.8	0.4
12 volts	1.3 44.4%	3 100%	1.8 60%	3 100%	3 100%	2.4	0.8
18 volts	3 100%	3 100%	1.5 50%	3 100%	3 100%	2.7	0.7
MEAN±SD	2.5±0.8	2.8±0.5	2.3±0.8	3±0	3±0		
	<b>3<sup>rd</sup> week (27.8.2015)</b>						
0 volt (control)	4 (100%)	4 (100%)	4 (100%)	3.2 (100%)	4 (100%)	3.8	0.4
6 volts	3.5 87.5%	3.5 87.5%	4 100%	3.7 114.6%	4 100%	3.7	0.3
12 volts	3 75%	4 100%	3.2 80%	3.8 117.2%	3.8 93.8%	3.5	0.4
18 volts	3.4 85%	3.5 87.5%	3 75%	3.5 109.4%	3.6 90%	3.4	0.2
MEAN±SD	3.5±0.4	3.75±0.3	3.6±0.5	3.5±0.2	3.8±0.2		

Twelve volts significantly decreased number of leaves of genotype Gm2 (23.8%), and 18 volts significantly decreased number of leaves of genotype Gm8 (29%). Treatment with 6 volts significantly enhanced number of leaves of genotypes Gm5 (41.9%), Gm6 (40.7%) and Gm34 (57.9%), but 6 volts significantly decreased number of leaves of genotype Gm8 by 16.7%. Results in Table 2 b (6<sup>th</sup> week) show that 12 and 18 volts decreased number of leaves of the five genotypes. Twelve volts significantly decreased number of leaves of genotype Gm2 (25%), and 18 volts significantly decreased number of leaves of genotypes Gm6 (42.5%) and Gm8 (55.8%), while 18 volts significantly enhanced number of leaves of genotype Gm2 (97.5%). Also, 6 volts significantly enhanced number of leaves of genotypes Gm5 (15.2%),

Gm6 (60.7%) and Gm34 (88.9%). Results in Table 2 c (7<sup>th</sup> week) show that 12 and 18 volts significantly decreased number of leaves of genotype Gm6 by 25.5% and 18 volts significantly enhanced number of leaves of genotype Gm2 by 98.6%. Also, 6 volts significantly enhanced number of leaves of genotypes Gm5 (87.6%), Gm8 (66.7%) and Gm34 (44.3%). Results in Table 2 c (8<sup>th</sup> week) show that generally 6 and 12 volts increased number of leaves of the five genotypes. Six volts significantly enhanced number of leaves of genotypes Gm5 (37%), Gm8 (82.3%) and Gm34 (159.7%). Also, 12 volts significantly enhanced number of leaves of genotypes Gm5 (70.4%) and Gm8 (74.1%), while 18 volts effect was not significant for the five genotypes.

**Table 2 b:** Number of leaves of guar genotypes 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> weeks after treatment

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	4 <sup>th</sup> week (3.9.2015)						
0 volt (control)	5.4 (100%)	5.8 (100%)	6.3 (100%)	5.6 (100%)	5.4 (100%)	5.7	0.4
6 volts	4.7 86.4%	6.3 108.7%	6.7 106.7%	5.7 101.2%	6 111.1%	5.9	0.8
12 volts	4.7 86.4%	5 87%	5.6 89.6%	5.8 102.7%	5 92.6%	5.2	0.5
18 volts	6 111.1%	5.3 91.3%	5 80%	4.3 77.4%	4.6 85.2%	5.0	0.6
MEAN±SD	5.2±0.6	5.6±0.6	5.9±0.7	5.3±0.7	5.3±0.6		
Treatments	5 <sup>th</sup> week (10.9.2015)						
0 volt (control)	7 (100%)	7.8 (100%)	9 (100%)	8.8 (100%)	7.6 (100%)	8.0	0.8
6 volts	6.2 88.1%	11 141.9%	12.7 140.7%	7.3 83.3%	12 157.9%	9.8	2.9
12 volts	5.3 76.2%	7 90.3%	10 111.1%	8 90.9%	5.5 72.4%	7.2	1.9
18 volts	8 114.3%	6.5 83.9%	6.5 72.2%	6.3 71%	6.3 82.2%	6.7	0.7
MEAN±SD	6.6±1.1	8.1±2.0	9.5±2.6	7.6±1.1	7.8±2.9		
Treatments	6 <sup>th</sup> week (17.9.2015)						
0 volt (control)	8 (100%)	8.3 (100%)	18.3 (100%)	13 (100%)	9 (100%)	11.3	4.4
6 volts	7.7 95.8%	9.5 115.2%	29.3 160.7%	14 107.7%	17 188.9%	15.5	8.6
12 volts	6 75%	8 97%	19 104.1%	12 92.3%	5 55.6%	10.0	5.7
18 volts	15.8 197.5%	8 97%	10.5 57.5%	5.8 44.2%	7.8 86.1%	9.6	3.9
MEAN±SD	9.4±4.4	8.4±0.7	19.3±7.7	11.2±3.7	9.7±5.2		

The results in Table 2 c (9<sup>th</sup> week) show that all treatments increased number of leaves of the five genotypes. Six volts had the highest mean value of increase. The highest percentage of increase by 6 volts was 192.3% in genotype Gm34, and the least one was 20.8 % in genotype gm6. The results in Table 2 d (10<sup>th</sup> week) show that 6 volts significantly enhanced number of leaves of genotype Gm34 by 222.7%, and 12 volts significantly enhanced number of

leaves of genotypes Gm2 (27.2%) and Gm5 (65.5%). Also, 18 volts significantly enhanced number of leaves of genotypes Gm2 (39.3%) and Gm6 (64.5%), while 18 volts significantly decreased number of leaves of genotype Gm8 by 38.8%. The results in Table 2 d (13<sup>th</sup> week) show that all treatments increased number of leaves of the five genotypes. Eighteen volts had the highest mean value of

**Table 2 c:** Number of leaves of guar genotypes 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> weeks after treatments

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	7 <sup>th</sup> week (24.9.2015)						
0 volt (control)	13.8 (100%)	21.5 (100%)	36.3 (100%)	21 (100%)	17.4 (100%)	22.0	8.6
6 volts	11.3 82.1%	40.3 187.6%	35.7 98.4%	35 166.7%	42.5 244.3%	33.0	12.5
12 volts	14.7 106.3%	24 111.6%	27 74.5%	31.5 150%	6 34.5%	20.6	10.2
18 volts	27.4 198.6%	14 65.1%	27 74.5%	11.3 53.6%	14 80.5%	18.7	7.8
MEAN±SD	16.8±7.2	25.0±11.1	31.5±5.2	24.7±10.8	20.0±15.8		
Treatments	8 <sup>th</sup> week (1.10.2015)						
0 volt (control)	23 (100%)	27 (100%)	46.5 (100%)	23.4 (100%)	19.3 (100%)	27.8	10.8
6 volts	24.1 105%	37 137%	51 109.7%	42.7 182.3%	50 259.7%	41.0	11.0
12 volts	25 108.7%	46 170.4%	31.8 68.4%	40.8 174.1%	8.3 42.9%	30.4	14.8
18 volts	32.2 140%	25.3 93.5%	39 83.9%	19.3 82.3%	17.8 92.2%	26.7	8.9
MEAN±SD	18.0±12.1	33.8±9.6	34.1±23.3	31.5±11.9	23.8±18.1		
Treatments	9 <sup>th</sup> week (8.10.2015)						
0 volt (control)	34 (100%)	37.5 (100%)	71.8 (100%)	35.8 (100%)	24.8 (100%)	40.8	18.0
6 volts	32 94.1%	71 189.3%	86.7 120.8%	74.7 208.6%	72.5 292.3%	67.4	20.7
12 volts	41.7 122.5%	67 178.7%	51.4 71.6%	57.8 161.6%	11 44.4%	45.8	21.5
18 volts	48.2 141.8%	32.3 86%	71 99%	35.3 98.7%	21 84.7%	41.6	19.1
MEAN±SD	39.0±7.4	51.9±19.9	70.2±14.5	50.9±19.0	32.3±27.4		

Increase. It significantly enhanced number of leaves of genotypes Gm2 by 17.4% and Gm6 by 180.9%.

**3.5.3. Stem diameter:** Table 3a (1<sup>st</sup> week) shows that all treatments reduced stem diameter of the five genotypes when compared with control plants. Eighteen volts had the highest mean value of reduction. It significantly reduced stem diameter of genotype Gm6 by 10%, while 18 volts significantly enhanced stem diameter of genotypes Gm8 (11.2%) and Gm34 (11.1%). The results in Table 3 a (2<sup>nd</sup> week) show that all treatments increased stem diameter of the five genotypes when compared with control plants. Twelve volts had the highest mean value of induction. It significantly enhanced stem diameter of genotype Gm2 by

8.3%, while 12 volts significantly decreased stem diameter of genotype Gm34 by 5.6%.

Table 3 a (3<sup>rd</sup> week) shows that 6 volts significantly enhanced stem diameter of genotype Gm2 by 17.6%, and significantly decreased stem diameter of genotypes Gm6 (5.9%) and Gm34 (5.3%). Also, 18 volts significantly reduced stem diameter of genotypes Gm5 (5.6%) and Gm34 (5.3%), and significantly enhanced stem diameter of genotype Gm8 by 5.6%, while the effect of 12 volts was not significant for stem diameter of the five genotypes. Results in Table 3 b (4<sup>th</sup> week) show that 6 volts increased stem diameter of the five genotypes when compared with control plants. It significantly enhanced stem diameter of genotypes Gm5 (36.8%), Gm6 (28.6%) and Gm34 (11.1%).

Table 2 d: Number of leaves of guar genotypes 10<sup>th</sup> and 13<sup>th</sup> weeks after treatments

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
<b>Treatments</b>	<b>10<sup>th</sup> week (15.10.2015)</b>						
0 volt (control)	44.8 (100%)	55 (100%)	97.3 (100%)	69.3 (100%)	29.8 (100%)	59.2	25.7
6 volts	42.3 94.4%	76 138.2%	83.7 86%	74.3 107.2%	96 322.7%	74.5	19.9
12 volts	57 127.2%	91 165.5%	52.2 53.7%	64 92.3%	14 47.1%	55.6	27.7
18 volts	62.4 139.3%	38.8 70.5%	160 164.5%	42.4 61.2%	30.2 101.5%	66.8	53.4
MEAN ± SD	51.6 ± 9.6	65.2 ± 23.0	98.3 ± 45.3	62.5 14.1	42.5 ± 36.5		
	<b>13<sup>th</sup> week (6.11.2015)</b>						
0 volt (control)	62.2 (100%)	68.8 (100%)	158.8 (100%)	91 (100%)	38.2 (100%)	83.8	45.9
6 volts	50.9 81.8%	109.3 159%	165.7 104.4%	161 176.9%	138.5 362.6%	125.1	47.1
12 volts	65 104.5%	152 221.1%	126.8 79.9%	146.5 161%	26.5 69.4%	103.4	55.1
18 volts	73 117.4%	60.8 88.4%	446 280.9%	77.3 84.9%	32.8 85.7%	138.0	173.1
MEAN ± SD	62.8 ± 9.2	97.7 ± 42.0	224.3 ± 148.8	118.9 ± 41.0	59.0 ± 53.2		

Twelve and 18 volts decreased stem diameter of the five genotypes. Twelve volts significantly decreased stem diameter of genotype Gm34 by 7.4%. Also, 18 volts significantly reduced stem diameter of genotype Gm34 by 9.5%, while 18 volts significantly enhanced stem diameter of genotype Gm2 by 10%. Table 3 b presents the results of 5<sup>th</sup> week and shows that 12 volts significantly decreased stem diameter of genotypes Gm5 (16%), Gm8 (8.3%) and Gm34 (8.7%), but significantly enhanced stem diameter of genotype Gm2 by 9.1%. Also, 18 volts significantly enhanced stem diameter of genotype Gm2 by 13.6%, and significantly decreased stem diameter of genotypes Gm5 (20%) and Gm6 (25%). Treatments with 6 volts was not effective for stem diameter of the five genotypes. The results presented in Table 3 b (6<sup>th</sup> week) show that 6 volts increased stem diameter of the five genotypes when compared with control plants. It significantly enhanced stem

diameter of genotype Gm5 by 19.2%, and significantly decreased stem diameter of genotype Gm8 by 15.4%.

Also, 12 volts significantly decreased stem diameter of genotype Gm34 by 8.3%, and 18 volts significantly decreased stem diameter of genotypes Gm6 (32.8%) and Gm8 (11.5%), while 18 volts significantly enhanced stem diameter of genotype Gm2 by 33.3% (i.e. radial growth of the stem). Significant increase in stem diameter might be due to either increase in cell enlargement or increase in cell division (i.e. isodiametric growth). Both growth phenomena are related to increased levels of specific groups of growth hormones such as auxins and cytokinins respectively. Anatomical study may help in exploring this effect. Results shown in Table 3 c (7<sup>th</sup> week) indicate that 6 volts increased stem diameter of the five genotypes when compared with control plants.

Table 3a: Stem diameter (mm) of guar genotypes 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> weeks after treatments with electric field

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
<b>Treatments</b>	<b>1<sup>st</sup> week (13.8.2015)</b>						
0 volt (control)	5.4 (100%)	6 (100%)	6.7 (100%)	5.7 (100%)	6 (100%)	5.9	0.5
6 volts	5 92.6%	5.7 94.4%	6 90%	5.3 94.1%	6.5 108.3%	5.7	0.6
12 volts	5.7 104.9%	7 116.7%	6.3 94.5%	6 105.9%	6 100%	4.9	2.8
18 volts	6.3 116.7%	5.7 94.4%	6 90%	6.3 111.2%	6.7 111.1%	3.7	3.4
MEAN±SD	4.0±2.7	6.1±0.6	4.7±3.1	4.3±2.8	6.3±0.3		
	<b>2<sup>nd</sup> week (20.8.2015)</b>						
0 volt (control)	6 (100%)	5.7 (100%)	6.3 (100%)	5.7 (100%)	6 (100%)	5.9	0.3
6 volts	6 100%	5.7 100%	6 94.7%	7 123.5%	5.5 91.7%	6.0	0.6
12 volts	6.5 108.3%	6 105.9%	6.3 100%	6 105.9%	5.7 94.4%	6.1	0.3
18 volts	5.7 95%	6.3 111.8%	6 94.7%	6 105.9%	5.7 94.4%	5.9	0.3
MEAN±SD	6.1±0.3	5.9±0.3	6.2±0.2	6.2±0.6	5.7±0.2		
	<b>3<sup>rd</sup> week (27.8.2015)</b>						
0 volt (control)	5.7 (100%)	6 (100%)	5.7 (100%)	6 (100%)	6.3 (100%)	5.9	0.3
6 volts	6.7 117.6%	6 100%	5.3 94.1%	6 100%	6 94.7%	6	0.5

12 volts	5.7100%	6 100%	6 105.9%	6 100%	6.3 100%	6	0.2
18 volts	6 105.9%	5.7 94.4%	5.5 97.1%	6.3 105.6%	6 94.7%	5.9	0.3
MEAN±SD	6±0.5	5.9±0.2	5.6±0.3	6.1±0.2	6.2±0.2		

It significantly enhanced stem diameter of genotype Gm6 by 22.6%. Twelve and 18 volts decreased stem diameter of the five genotypes. Twelve volts significantly decreased stem diameter of genotype Gm34 by 32.3%. Also, 18 volts significantly decreased stem diameter of genotypes Gm5 (15.2%), Gm8 (25%) and Gm34 (16.1%), while 18 volts significantly enhanced stem diameter of genotype Gm2 by

33.3%. Table 3 c (8<sup>th</sup> week) shows that 6 and 18 volts increased stem diameter of the five genotypes when compared with control plants. Six volts had the highest mean value of increase. It significantly enhanced stem diameter of genotypes Gm5 (30.3%), Gm6 (26.7%) and Gm8 (12.9%).

**Table 3 b:** Stem diameter (mm) of guar genotypes 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	4 <sup>th</sup> week (3.9.2015)						
0 volt (control)	6.7 (100%)	6.3 (100%)	7 (100%)	7 (100%)	7.3 (100%)	6.9	0.4
6 volts	6.7 100%	8.7 136.8%	9 128.6%	6.7 95.2%	6.5 111.1%	7.5	1.2
12 volts	6.3 95%	7 110.5%	7.3 104.8%	7.3 104.8%	6 92.6%	6.8	0.6
18 volts	7.3 110%	6.3 100%	6 85.7%	6.3 90.5%	7 85.2%	6.6	0.5
MEAN±SD	6.8±0.4	7.1±1.1	7.3±1.2	6.8±0.4	6.7±0.6		
Treatments	5 <sup>th</sup> week (10.9.2015)						
0 volt (control)	7.3 (100%)	8.3 (100%)	8.7 (100%)	8 (100%)	7.7 (100%)	8	0.5
6 volts	7.3 100%	8.7 104%	9.3 107.7%	7.7 95.8%	8 104.3%	8.2	0.8
12 volts	8 109.1%	7 84%	8.7 100%	7.3 91.7%	7 91.3%	7.6	0.7
18 volts	8.3 113.6%	6.7 80%	6.5 75%	7.7 95.8%	7.7 100%	7.4	0.8
MEAN±SD	7.8±0.5	7.7±1.0	8.3±1.2	7.7±0.3	7.6±0.4		
Treatments	6 <sup>th</sup> week (17.9.2015)						
0 volt (control)	7 (100%)	8.7 (100%)	9.7 (100%)	8.7 (100%)	8 (100%)	8.4	1.0
6 volts	7 100%	10.3 119.2%	12 124.1%	7.3 84.6%	8.5 106.3%	9.0	2.1
12 volts	7.7 123.8%	9 103.8%	9.7 100%	8.3 96.2%	7.3 91.7%	8.4	1.0
18 volts	9.3 133.3%	7.7 88.5%	6.5 67.2%	7.7 88.5%	7.7 95.8%	7.8	1.0
MEAN±SD	7.8±1.1	8.9±1.1	9.5±2.3	8±0.6	7.9±0.5		

Twelve volts decreased stem diameter of the five genotypes. It significantly decreased stem diameter of genotype Gm34 by 31.3%, while 12 volts significantly enhanced stem diameter of genotype Gm6 by 16.7%. Results in Table 3 c (9<sup>th</sup> week) show that 12 and 18 volts decreased stem diameter of the five genotypes when compared with control plants, while 6 volts increased stem diameter of the five genotypes. It significantly enhanced stem diameter of

genotypes Gm6 (20.6%) and Gm8 (9.7%). Also, 12 volts significantly enhanced stem diameter of genotype Gm2 by 23.1%, but significantly decreased stem diameter of genotype Gm34 (31.4%). Also, 18 volts significantly reduced stem diameter of genotypes Gm5 (16.2%) and Gm8 (9.7%). While 18 volts significantly enhanced stem diameter of genotype Gm2 by 38.5%. Results in Table 3 d

**Table 3 c:** Stem diameter (mm) of guar genotypes 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm <sub>2</sub>	Gm <sub>5</sub>	Gm <sub>6</sub>	Gm <sub>8</sub>	Gm <sub>34</sub>	MEAN	SD
Treatments	7 <sup>th</sup> week (24.9.2015)						
0 volt (control)	10 (100%)	11 (100%)	10.3 (100%)	10.7 (100%)	10.3 (100%)	10.5	0.4
6 volts	10 100%	12 109.1%	12.7 122.6%	10.0 93.7%	10.0 96.8%	10.9	1.3
12 volts	10.3 103.3%	10 90.9%	11 106.5%	10.3 96.9%	7 67.7%	9.7	1.6
18 volts	13.3 133.3%	9.3 84.8%	9.5 91.9%	8 75%	8.7 83.9%	9.8	2.1
MEAN±SD	10.9±1.6	10.6±1.2	10.9±1.3	9.8±1.2	9.0±1.5		
Treatments	8 <sup>th</sup> week (1.10.2015)						
0 volt (control)	8.7 (100%)	11 (100%)	10 (100%)	10.3 (100%)	10.7 (100%)	10.1	0.9
6 volts	9.3 107.7%	14.3 130.3%	12.7 126.7%	11.7 112.9%	11.5 107.8%	11.9	1.8
12 volts	9.7 111.5%	10 90.9%	11.7 116.7%	11 106.5%	7.3 68.7%	9.9	1.7
18 volts	12 138.5%	9.7 87.9%	10.5 105%	10.3 100%	11.3 106.2%	10.8	0.9
MEAN±SD	9.9±1.4	11.3±2.1	11.2±1.2	10.8±0.6	10.2±2.0		
Treatments	9 <sup>th</sup> week (8.10.2015)						
0 volt (control)	8.7 (100%)	12.3 (100%)	11.3 (100%)	10.3 (100%)	11.7 (100%)	10.9	1.4
6 volts	9 103.8%	13.7 110.8%	13.7 120.6%	11.3 109.7%	12 102.9%	11.9	1.9
12 volts	10.7 123.1%	12 97.3%	11.3 100%	10.7 103.2%	8 68.6%	10.5	1.5
18 volts	12 138.5%	10.3 83.8%	10 88.2%	9.3 90.3%	10 85.7%	10.3	1
MEAN±SD	10.1±1.5	12.1±1.4	11.6±1.5	10.4±0.8	10.4±1.8		

(10<sup>th</sup> week) show that generally all treatments increased stem diameter of the five genotypes when compared with control plants. Six volts had the highest mean value of increase. It significantly enhanced stem diameter of genotypes Gm5 (13.6%) and Gm6 (19.4%). Also, 12 volts significantly enhanced stem diameter of genotypes Gm2 (18.7%), Gm6 (19.4%) and Gm8 (8.6%), while 12 volts significantly decreased stem diameter of genotype Gm34 by 24.3%. Also, 18 volts significantly reduced stem diameter of genotype Gm6 by 15.9%, but significantly enhanced stem diameter of genotypes Gm2 (37.5%) and Gm6 (12.5%). Results in Table 3 d (11<sup>th</sup> week) show that 6 volts increased stem diameter of the five genotypes when compared with control plants. It significantly enhanced stem diameter of genotypes Gm5 (23.7%), Gm6 (14.3%), Gm8 (11.1%) and Gm34 (17.6%). Also, 18 volts

significantly enhanced stem diameter of genotype Gm2 by 20.6%, and 12 volts significantly enhanced stem diameter of Genotype Gm8 by 16.7%. While 12 volts significantly reduced stem diameter of genotype Gm34 by 24.3%.

Results in Table 3 d (12<sup>th</sup> week) show that all treatments increased stem diameter of the five genotypes when compared with control plants. Six volts had the highest mean value of increase. It significantly enhanced stem diameter of genotypes Gm6 (20%), Gm8 (17.1%) and Gm34 (17.6%).

**3.5.4. Number of branches:** Results in Table 4 a (6<sup>th</sup> week) show that 12 and 18 volts decreased the number of branches of the five genotypes, while 6 volts increased the number of branches of the five genotypes when compared with control plants.

**Table 3 d:** Stem diameter (mm) of guar genotypes 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
Treatments	10 <sup>th</sup> week (15.10.2015)						
0 volt (control)	10.7 (100%)	14.7 (100%)	12 (100%)	11.7 (100%)	12.3 (100%)	12.3	1.5
6 volts	11.7 109.4%	16.7 113.6%	14.3 119.4%	12 102.9%	13.5 109.5%	13.6	2.0
12 volts	12.7 118.7	13 88.6%	14.3 119.4%	12.7 108.6%	9.3 75.7%	12.4	1.8
18 volts	14.7 137.5%	12.3 84.1%	13.5 112.5%	12 102.9%	10.7 86.5%	12.6	1.5
MEAN±SD	12.4±1.7	14.2±1.9	13.5±1.1	12.1±0.4	11.5±1.8		
Treatments	11 <sup>th</sup> week (22.10.2015)						
0 volt (control)	11.3 (100%)	12.7 (100%)	14 (100%)	12 (100%)	12.3 (100%)	12.5	1.0
6 volts	10.7 94.1%	15.7 123.7%	16 114.3%	13.3 111.1%	14.5 117.6%	14.0	2.2
12 volts	12 105.9%	12 94.7%	14.7 104.8%	14 116.7%	9.3 75.7%	12.4	2.1
18 volts	13.7 120.6%	10.7 84.2%	13 92.9%	12.7 105.6%	11.7 94.6%	12.3	1.2
MEAN±SD	11.9±1.3	12.8±2.1	14.4±1.3	13±0.9	12.0±2.1		
Treatments	12 <sup>th</sup> week (29.10.2015)						
0 volt (control)	10.7 (100%)	14 (100%)	13.3 (100%)	11.7 (100%)	12.3 (100%)	12.4	1.3
6 volts	11 103.1%	15.3 109.5%	16 120%	13.7 117.1%	14.5 117.6%	14.1	1.9
12 volts	13 121.9%	17 121.4%	13.7 102.5%	13 111.4%	10 81.1%	13.3	2.5
18 volts	14.7 137.5%	12 85.7%	15.5 116.3%	13 111.4%	11.7 94.6%	13.4	1.7
MEAN±SD	12.3±1.9	14.6±2.1	14.6±1.3	12.8±0.8	12.1±1.9		

It significantly enhanced the number of branches of genotypes Gm5 (155.6%), Gm6 (106.1%) and accelerate branching in genotype Gm34, while 6 volts significantly decreased the number of branches of genotype Gm8 by 58.9%. Results in Table 4 a (7<sup>th</sup> week) show that 12 and 18 volts decreased the number of branches of the five genotypes, and just 6 volts increased the number of branches of the five genotypes when compared with control plants. It significantly enhanced the number of branches of genotypes Gm8 (108.3%) and Gm34 (162.5%). Results in Table 4 a (8<sup>th</sup> week) show that 12 and 18 volts increased the number of branches of the five genotypes, and just 6 volts decreased the number of branches of the five genotypes when compared with control plants. It significantly enhanced the number of branches of genotypes Gm5 (72.8%), Gm8 (115.3%) and Gm34 (171.7%). Results in Table 4 b (9<sup>th</sup> week) show that 12 and 18 volts decreased the number of branches of the five genotypes. And just 6 volts increased the number of branches of the five genotypes when compared with control plants. It significantly enhanced the number of branches of genotypes Gm5 (121%), Gm6 (16.3%), Gm8 (86%) and Gm34 (163.2%). Results in Table 4 b (10<sup>th</sup> week) show that 6 volts significantly enhanced the number of branches of genotypes Gm5 (70.1%), Gm8 (84.6%) and Gm34 (155.7%). Also, 18 volts significantly enhanced the number of branches of genotypes Gm2 (34.4%) and Gm6 (24.7%), and 12 volts

significantly enhanced the number of branches of genotype Gm8 (67.3%), while 12 volts significantly decreased the number of branches of genotype Gm6 by 27.7%. It is obvious that hormones diffuse within different parts of plants in variant and very little concentrations. The phototropism is caused by the effect of sun light on plant hormones. Knowing that light is a wave form of electromagnetic field, hence this phototropism is regarded as a bio-electromagnetic effect mainly due to the interaction of plant cells with the electric field of light. This explains how exerting electric field (on biological sample) affects the enhancement of plant height and branching by producing gibberellic acid and cytokinins hormones respectively.

**3.5.5. Number of nodes:** Results in Table 5 (8<sup>th</sup> week) show that 6 and 12 volts increased the number of nodes of the five genotypes, and just 18 volts decreased the number of nodes of the five genotypes when compared with control plants. Six volts significantly enhanced the number of nodes of genotypes Gm5 (71%), Gm8 (73.5%) and Gm34 (138.2%). Also, 18 volts significantly enhanced the number of nodes of genotype Gm2 by 42.4%, and 12 volts significantly enhanced the number of nodes of genotypes Gm5 (56.5%) and Gm8 (57.2%), while 12 volts significantly decreased the number of nodes of genotype Gm6 by 26.3%. Results in Table 5 (9<sup>th</sup> week) show that 6 and 12 volts increased the number of nodes of the five genotypes, and just 18 volts

decreased the number of nodes of the five genotypes when compared with control plants. Six volts significantly enhanced the number of nodes of genotypes Gm5 (111.2%),

Gm6 (24.5), Gm8 (68.7%) and Gm34 (163.5%). Also, 18 volts significantly enhanced the number of nodes of genotype Gm2 by 26.1%, and 12 volts significantly

**Table 4 a:** Number of branches of guar genotypes 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> weeks after treatments with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
Treatments	6 <sup>th</sup> week (17.9.2015)						
0 volt (control)	0 (100%)	1.5 (100%)	2.8 (100%)	0.8 (100%)	0 (100%)	1.0	1.2
6 volts	0	5.3 (355.6%)	5.7 (206.1%)	0.3 (41.7%)	2.5	2.8	2.7
12 volts	0	0	3 (109.1%)	0.3 (31.3%)	0	0.7	1.3
18 volts	1.8	0	0	0	0	0.4	0.8
MEAN±SD	0.5±0.9	1.7±2.5	2.9±2.3	0.3±0.3	0.6±1.3		
Treatments	7 <sup>th</sup> week (24.9.2015)						
0 volt (control)	3 (100%)	6 (100%)	8.3 (100%)	4 (100%)	4 (100%)	5.1	2.1
6 volts	2.8 (94.4%)	8.3 (138.9%)	8 (97%)	8.3 (208.3%)	10.5 (262.5%)	7.6	2.8
12 volts	2 (66.7%)	4 (66.7%)	5.4 (65.5%)	8.3 (206.3%)	0	3.9	3.2
18 volts	6.6 (220%)	2 (33.3%)	4.5 (54.5%)	1.5 (37.5%)	2.3 (56.3%)	3.4	2.1
MEAN±SD	3.6±2.0	5.1±2.7	6.5±1.9	5.5±3.4	4.2±4.5		
Treatments	8 <sup>th</sup> week (1.10.2015)						
0 volt (control)	4.4 (100%)	6.8 (100%)	10.5 (100%)	4.8 (100%)	4.6 (100%)	6.2	2.6
6 volts	4.6 (103.9%)	11.7 (172.8%)	12 (114.3%)	10.3 (215.3%)	12.5 (271.7%)	10.2	3.3
12 volts	5.7 (128.8%)	9 (133.3%)	7.6 (72.4%)	11 (229.2%)	0	6.7	4.2
18 volts	8 (181.8%)	3.8 (55.6%)	6 (75.1%)	3 (62.5%)	2.5 (54.3%)	4.7	2.3
MEAN±SD	5.7±1.7	7.8±3.4	9.0±2.7	7.3±4.0	4.9±5.4		

enhanced the number of nodes of genotypes Gm5 (60.6%) and Gm8 (56.6%), while 12 volts significantly decreased the number of nodes of genotype Gm6 by 17%. Results in Table 5 (10<sup>th</sup> week) show that all treatments increased the number of nodes of the five genotypes. Six volts significantly enhanced the number of nodes in genotypes Gm5 (53.5%),

Gm8 (78.4%) and Gm34 (17.3%). Also, 18 volts significantly enhanced the number of nodes in genotype Gm2 by 46.8%, and 12 volts significantly enhanced the number of nodes in genotypes Gm5 (69.3%) and Gm8 (59.3%), while 12 volts significantly decreased the number of nodes in genotype Gm6 by 22%.

**Table 4 b:** Number of branches of guar genotypes 9<sup>th</sup> and 10<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	±SD
Treatments	9 <sup>th</sup> week (8.10.2015)						
0 volt (control)	8.8 (100%)	8.8 (100%)	21.5 (100%)	8.6 (100%)	7.6 (100%)	11.1	5.9
6 volts	7.9 (89.3%)	19.3 (221%)	25 (116.3%)	16 (186%)	20 (263.2%)	17.6	6.3
12 volts	8.3 (94.7%)	13 (148.6%)	17.4 (80.9%)	14.3 (165.7%)	2 (26.3%)	11.0	6.0
18 volts	11.2 (127.3%)	8.3 (94.3%)	19.5 (90.7%)	5.5 (64%)	5.6 (73.7%)	10.0	5.8
MEAN±SD	9.0± 1.5	12.3± 5.1	20.9± 3.2	11.1± 4.9	8.8± 7.8		
Treatments	10 <sup>th</sup> week (15.10.2015)						
0 volt (control)	12.8 (100%)	14.5 (100%)	23.3 (100%)	13 (100%)	8.8 (100%)	14.5	5.3
6 volts	10.6 (82.6%)	24.7 (170.1%)	25 (107.5%)	24 (184.6%)	22.5 (255.7%)	21.3	6.1
12 volts	14 (109.4%)	15 (103.4%)	16.8 (72.3%)	21.8 (167.3%)	2.5 (28.4%)	14.0	7.1
18 volts	17.2 (134.4%)	10.5 (72.4%)	29 (124.7%)	10 (76.9%)	6.5 (73.9%)	14.6	8.9
MEAN±SD	13.6±2.8	16.2±6.0	23.5±5.1	17.2±6.7	10.1±8.7		

**3.5.6. Number of flowers:** Table 6 a (9<sup>th</sup> week) shows that all treatments increased the number of flowers of the five genotypes. Six volts significantly enhanced the number of flowers of genotypes Gm6 (100%), Gm8 (316.7%) and accelerated flowering of genotype Gm34. Also, 12 volts significantly enhanced the number of flowers of genotype Gm8 by 2712.5%, and 18 volts significantly enhanced the number of flowers of genotypes Gm5 (200%), Gm6 (166.7%) and Gm8 (25%). The results in Table 6 a (10<sup>th</sup> week) show that 6 and 12 volts decreased the number of flowers of the five genotypes. Six volts significantly decreased the number of flowers of genotypes Gm5 and

Gm8, and significantly enhanced the number of flowers of genotype Gm34. Also, 12 volts significantly decreased the number of flowers of genotypes Gm5 and Gm8, and 18 volts significantly decreased the number of flowers of genotype Gm8, while 18 volts significantly enhanced the number of flowers of genotype Gm6 by 100%. Results shown in Table 6 b (11<sup>th</sup> week) indicate that 6 volts increased the number of flowers of all five genotypes. It significantly enhanced the number of flowers of genotype Gm34, and significantly decreased the number of flowers of genotypes Gm2 and Gm5. Also,

**Table 5:** Number of nodes of guar genotypes 8<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
Treatments	8 <sup>th</sup> week (1.10.2015)						
0 volt (control)	17 (100%)	23 (100%)	35 (100%)	19.4 (100%)	17 (100%)	22.3	7.5
6 volts	16.1 95%	39.3 171%	38 108.6%	33.7 173.5%	40.5 238.2%	33.5	10.1
12 volts	16.7 98%	36 156.5%	25.8 73.7%	30.5 157.2%	9.3 54.4%	23.6	10.7

18 volts	24.2 142.4%	19 82.6%	31 88.6%	14.8 76%	13.2 77.6%	20.4	7.3
MEAN±SD	18.5±3.8	29.3±9.9	32.5±5.3	24.6±9.0	20.0±14.0		
9 <sup>th</sup> week (8.10.2015)							
0 volt (control)	30.6 (100%)	34.3 (100%)	67.8 (100%)	33.2 (100%)	29.6 (100%)	39.1	16.1
6 volts	27.9 91%	72.3 211.2%	84.3 124.5%	56, 168.7%	78 263.5%	63.7	22.6
12 volts	31.7 103.5%	55 160.6%	56.2 83%	52 156.6%	13.5 45.6%	43.5	20.7
18 volts	38.6 126.1%	28.8 83.9%	66.5 98.2%	23.3 70%	27.8 93.8%	37.0	17.4
MEAN±SD	32.2±4.6	47.6±20.0	70.9±9.0	41.1±15.5	37.2±28.1		
10 <sup>th</sup> week (15.10.2015)							
0 volt (control)	44.4 (100%)	53.8 (100%)	90.3 (100%)	51 (100%)	34.4 (100%)	54.8	21.2
6 volts	40.4 91.1%	82.5 153.5%	106 117.5%	91 178.4%	93 270.3%	82.6	25.0
12 volts	54 121.6%	91 169.3%	70.4 78%	81.3 159.3%	16.8 48.7%	62.7	29.1
18 volts	65.2 146.8%	40.3 74.9%	104.5 115.8%	39 76.5%	34.5 100.3%	56.7	29.3
MEAN±SD	51.0±11.0	66.9±23.9	92.8±16.5	65.6±24.6	44.7±33.3		

12 volts significantly decreased the number of flowers of genotypes Gm5 and Gm6, and significantly enhanced the number of flowers of genotype Gm8, while 18 volts significantly decreased the number of flowers of genotypes Gm5 and Gm8. The results in Table 6 b show that 6 volts affected the number of flowers of all five genotypes. It significantly enhanced the number of flowers of genotypes

Gm8 and Gm34, and significantly decreased the number of flowers of genotype Gm2. Also, 12 volts significantly decreased the number of flowers of genotypes Gm2 and Gm8, and significantly enhanced the number of flowers of genotype Gm5, while 18 volts significantly enhanced the number of flowers of genotype Gm6 by 122%.

**Table 6a:** Number of flowers of guar genotypes 9<sup>th</sup> and 10<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
9 <sup>th</sup> week (8.10.2015)							
0 volt (control)	0 (100%)	0.5 (100%)	1.5 (100%)	0.4 (100%)	0 (100%)	0.5	0.6
6 volts	0	0.3 66.7%	3 200%	1.7 425%	3	1.6	1.4
12 volts	0	0	1.6 106.7%	11.3 2812.5%	0	2.6	4.9
18 volts	0	1.5 300%	4 266.7%	0.5 125%	0	1.2	1.7
MEAN ± SD	0 ± 0	0.6 ± 0.6	2.5 ± 1.2	3.5 ± 5.2	0.8 ± 1.5		
10 <sup>th</sup> week (15.10.2015)							
0 volt (control)	0 (100%)	1.5 (100%)	1.8 (100%)	2.2 (100%)	0.2 (100%)	1.1	1.0
6 volts	0	0.3 20%	2 111.1%	0.3 13.6%	2.5 1250%	1.0	1.1
12 volts	0	0	1.2 66.7%	0.3 13.6%	0	0.3	0.5
18 volts	0	1.5 100%	3.5 194.4%	0.3 13.6%	0.5 250%	1.2	1.4
MEAN ± SD	0 ± 0	0.8 ± 0.8	2.1 ± 1.0	0.8 ± 1.0	0.8 ± 1.2		

**3.5.7. Moisture content**

Table 7 shows that 6 volts significantly reduced moisture content of genotypes Gm2, Gm5, Gm8 and Gm34, and 12 volts significantly reduced moisture content of genotypes

Gm2, Gm5 and Gm34, while 18 volts significantly reduced moisture content of genotype Gm5 and significantly enhanced moisture content of genotype Gm6.

**Table 6 b:** Number of flowers of guar genotypes 11<sup>th</sup> and 12<sup>th</sup> weeks after treatment with electric field

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
11 <sup>th</sup> week (22.10.2015)							
0 volt (control)	1.6 (100%)	4 (100%)	3.5 (100%)	2.2 (100%)	0 (100%)	2.3	1.6
6 volts	0.9 53.6%	2.3 58.3%	4 114.3%	3 136.4%	7	3.4	2.3
12 volts	2 125%	1 25%	2 57.1%	3.3 147.7%	0	1.7	1.2
18 volts	1.8 112.5%	0.3 6.3%	4 114.3%	1 45.5%	0.5	1.5	1.5
MEAN± SD	1.6± 0.5	1.9± 1.6	3.4± 0.9	2.4± 1.0	1.9± 3.4		
12 <sup>th</sup> week (27.11.2015)							
0 volt (control)	14 (100%)	19.8 (100%)	20.5 (100%)	18.2 (100%)	20.6 (100%)	18.6	2.8
6 volts	7.1 51%	15 75.9%	21.7 105.7%	21.7 119%	51 247.6%	23.3	16.6
12 volts	10 71.4%	29 146.8%	12.8 62.4%	15.2 83.5%	6.3 30.3%	14.7	8.7
18 volts	15.4 110%	16 81%	45.5 222%	16.3 89.3%	17 82.5%	22.0	13.1
MEAN± SD	11.6 ± 3.8	19.9 ± 6.4	25.1 ± 14.1	17.8 ± 2.8	23.7± 19.2		

**Table 7:** Moisture content of five genotypes of treated guar seeds

Genotypes	Treatments	Moisture content %
Gm2	0 volt (control)	106.4*
	6 volts	100.2
	12 volts	100.5
	18 volts	104.7
	Mean ± SD	102.95 ± 3.1

Gm5	0 volt (control)	115.4
	6 volts	103.2
	12 volts	88.4
	18 volts	99.4
	Mean $\pm$ SD	101.6 $\pm$ 11.1
Gm6	0 volt (control)	92.2
	6 volts	88.5
	12 volts	97.6
	18 volts	129.3
	Mean $\pm$ SD	101.9 $\pm$ 18.6
Gm8	0 volt (control)	141.4
	6 volts	117.4
	12 volts	129.2
	18 volts	149.8
	Mean $\pm$ SD	134.5 $\pm$ 14.2
Gm34	0 volt (control)	139.1
	6 volts	106.6
	12 volts	97.4
	18 volts	135.4
	Mean $\pm$ SD	119.6 $\pm$ 20.8

\*Mean value of 10 determinations  $\pm$  SD

#### 4. Conclusion

When the five genotypes of guar were treated with 0, 6, 12 and 18 volts in seedling stage, growth measurements during 12 weeks show that:

- All treatments reduced plant height of the five genotypes in the 1<sup>st</sup> to the 3<sup>rd</sup> weeks, and just 6 volts enhanced plant height in the 4<sup>th</sup> to the 10<sup>th</sup> weeks. But in the 11<sup>th</sup> week 18 volts reduced plant height, while in the 12<sup>th</sup> week all treatments enhanced plant height of the five genotypes.
- All treatments reduced number of leaves of the five genotypes in the 1<sup>st</sup> to the 4<sup>th</sup> weeks, and just 6 volts enhanced number of leaves in the 4<sup>th</sup> to the 7<sup>th</sup> weeks. In the 8<sup>th</sup> week, the treatment with 18 volts reduced the number of leaves, while in the 9<sup>th</sup> to the 13<sup>th</sup> weeks all treatments enhanced number of leaves of the five genotypes.
- All treatments reduced stem diameter of the five genotypes in the 1<sup>st</sup> and 2<sup>nd</sup> weeks. In the 3<sup>rd</sup> week all treatments have no effect on stem diameter, and just 6 volts enhanced stem diameter in the 4<sup>th</sup> to the 7<sup>th</sup> weeks. In the 8<sup>th</sup> week only 12 volts reduced stem diameter, but in the 9<sup>th</sup> week, treatments with 12 and 18 volts reduced stem diameter. In the 10<sup>th</sup> and 12<sup>th</sup> weeks all treatments enhanced stem diameter, while in the 11<sup>th</sup> week 6 volts only enhanced stem diameter of the five genotypes.
- In the 6<sup>th</sup> and the 7<sup>th</sup> weeks 6 volts enhanced number of branches of the five genotypes, but in the 8<sup>th</sup> week, the treatment with 18 volts reduced the number of branches. Also, 12 and 18 volts reduced number of branches in the 9<sup>th</sup> week, while in the 10<sup>th</sup> week 6 and 12 volts enhanced number of branches of the five genotypes.
- Treatment with 18 volts reduced number of nodes of the five genotypes in the 8<sup>th</sup> and 9<sup>th</sup> weeks, while in the 10<sup>th</sup> week all treatments enhanced number of nodes of the five genotypes.
- All treatments enhanced the number of flowers of the five genotypes in the 9<sup>th</sup> week, and only 18 volts enhanced number of flowers in the 10<sup>th</sup> week. In the 11<sup>th</sup> week only 6 volts enhanced the number of flowers, while in the 12<sup>th</sup> week 6 and 18 volts enhanced the number of flowers of the five genotypes.

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