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Effect of electric field on seed growth of five *Cyamopsis tetragonoloba* L. (guar) genotypes

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Abstract
The study aimed to investigate the effect of the application of external electric field on the seed germination and growth of five genotypes of *Cyamopsis tetragonoloba* L. plant (Gm2, Gm5, Gm6, Gm8 and Gm34). 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 was designed and used for experimentation with two copper plate's area (25 and 225 cm^2) and different voltage levels (0, 6, 9, 22.1 and 30 volts). Seeds of *C. tetragonoloba* were located within spaces between each capacitor's plates and are were exerted upon by different energy densities. The results showed that when five treatments (0, 6, 9, 22.1 and 30 volts) were used to the five genotypes in 12 days after treatments; all treatments resulted in inhibition of root growth and plant height in the germinating seeds either when 25 cm^2 or 225 cm^2 plate's area were used. Also, when 25 cm^2 and 225 cm^2 plate's area were used with one treatment of 6 volts for the five genotypes; 225 cm^2 plates were found more affective in the reduction of plant height than 25 cm^2 plates. When 25 cm^2 plates were used the highest reduction of radicle length was obtained by 9 volts. When the five genotypes were exposed to 6 volts by using 225 cm^2 plates; the genotype that was affected by the treatment in reducing radicle length was Gm2 in 3rd and 4th day after treatment. The less affected one was Gm5. The results suggested that electric field has direct effect on seed germination and development of *C. tetragonoloba* plants.

Keywords: electric filed- radicle length- seed germination – seed growth - voltage levels

1. Introduction

It is well known that cells of living organisms, in their molecular or rather atomic structure, are dominated by biochemical processes. These processes which cause the growth of the living entities, are due to interaction amongst their electrically charged constituents. Therefore, it is suggested that the growth of a plant is sensitively susceptible to external influence exerted by an electromagnetic force. There have been many studies performed in this area of science. Murr (1963) [17] showed that sufficiently high intensity fields have a definite effect on plant growth and growth responses. He also proposed that under certain conditions this can affect the charge balance in the ionosphere. Murr (1966) [18] also noted that, field delay or field intensity-time duration experiments on corn and bean plants allow a possible relationship between plant growth and storm conditions in the natural environment to be established. Stern (1991) [28] had noted that greater conditions of roots occur on the north and south sides of wheat seedlings and it has been suggested that magnetic forces may be involved. The term geomagnetotropism has bean proposed for this phenomenon. Some of this tropic or tropic-like responses have been induced primarily by artificial means, but others occur regularly in nature. More elaboration on this subject is discussed by Rajendra *et al.* (2005) [23], Inoue *et al.* (2005) [12] and Portier and Wolfe (1998) [22]. Other experiments were set up which include growing plant seeds inside an electric field. The results of these studies showed that the bean sprout in electric field had a better growth when compared to that without electric field based on statistical analysis (Kiatgamgorn *et al.*, (2002) [14]. Nechitailo and Gordeev (2004) [20] had carried out experiments on electrostimulation of different plants under space flight conditions at the orbital station MIR. They showed that the absorption of nutrient elements by the root system had increased to the optimal level. Many plant physiologists who are interested in plant irritability have always considered the galvanotropic response of the roots, which was discovered by Elfving in (1882) [4]. Many researchers have studied the galvanotropic response after that (Müller-Hettlingen, (1883) [16]; Brunchorst, (1884) [3], Rischawi, (1885) [24]; Ewart and Bayliss, (1906) [7]; Schellenberg, (1906) [26]; Gassner, (1906)[8]; Szücs, (1913) [29]; Stern, (1924) [27]). Based on all these observations, it is generally admitted that for high densities of current, or for long exposures, curvature towards the pole is obtained; that on the other hand, for lower densities of current, or for shorter exposures curvatures were reported. Dose effect have been studied by Robertson *et al.* (1981) [25]. He showed that when roots of *Pisum sativum* L. were exposed to an electric field at 430 v/m for two days, the growth rate was decreased by about 40%. When the electric field was terminated, the growth rate increased steadily and was almost normal after 5 days. At 470 v/m root growth rate was almost completely arrested. They referred these results to a narrow range of induced membrane potentials that spane the range form slightly altered to almost completely arrested growth rates. Miller *et al.* (1983) [15]

determined the growth rates of *P. sativum*. They found that root growth rates were affected in a dose dependent relationship by exposures greater than 250 v/m. Brayman and Miller (1989)[2] had made proportionality study of the bio-effect of electric field to the induction of transmembrane root. They found an inhibition of segmental root growth when segmental average voltmeter attained a value of 2.4-3.6 mv. In other species, growth inhibition occurred when voltmeter attained or exceeded 2.3 – 2.7 mv and segmental growth cessation was predicted to occur when segmental average voltmeter exceeded 7-9 mv. Behrens *et al.* (1982)[1] showed that the apparent density of the acropetal current in the root cap region increased and then decreased with time. They suggested a close connection between the current and the transduction of information from the root cap to the elongation zone following gravi- perception in the cap. Other studies (Inoue *et al.*, 1985) [11] showed that root growth rate decreased in proportion to the increasing strength. Hart and Schottenfeld (1979) [10] believed that the effects were due to loss of water from the leaf tips when corona current flowed caused by the high electric fields. More recent study in 2011 by El-Tahir [5] showed that 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 reduction in stem height.

2. Materials and Methods

2.1 Plant materials

Mature seeds of five genotypes of *Cyamopsis tetragonoloba* (Gm2, Gm5, Gm6, Gm8 and Gm34) harvest of January, 2014 was used for experimentations.

2.2 Source of electric field

In this study electrical supply system was used as source of electric field. It was designed by El-Tahir (2017) [6]. Simple representations of the system are shown in Fig. 1.

2.3 Experimental Set-Up

The system was varied in voltages and in plate's area. Therefore, plates area were 5x5 cm^2 (Group A) and 15x15 cm^2 (Group B). Voltages level were 6, 9, 22.1 and 30 V.

The System consisted of: Power supply AC electric source/ 220 volt/ 50 Hz, Multi output transformer, Multi rectifier, Two sets of capacitors A and B (first one consisted of 20 capacitors and the second consisted of 5 capacitors) connected in parallel, isolated electrical wire 7 metres in length, electrical connection, copper plates with two different areas A and B. (A= 5x5 cm^2, B=15x15 cm^2) and wooden pieces.

Fig 1: Set-up of the system

2.4 Germination of seeds:

The general procedure for seed germination can be summarized as follows: *C. tetragonoloba* seeds were selected carefully from each genotype and soaked in tap-water for 3-4 hrs. Then seeds were planted in Petri-dishes or in black polythene bags (20x30 cm) containing a soil mixture of sand and clay at the ratio of 1:1, v/v. The germinating seeds were supplied with sufficient water during the experimental period.

2.5 Growth measurements

The radicle length was recorded three days after treatments and plant height was measured each two days during the experimental period.

2.6 Treatment of seeds and seedlings with electric field

Imbibed seeds or young plants of the five genotypes of *C. tetragonoloba* were subjected to different doses of electric field. Method of treatment was described at the beginning of each experiment.

2.7 Experiment 1: - Exposure of *C. tetragonoloba* (guar) germinating seeds to electric field

This experiment was designed to investigate the effect of electric field on young seedlings of five genotypes of *C. tetragonoloba*. In this experiment groups A and B were used as described previously during three days after treatments.

2.7.1. Seed germination

Ten seeds of each genotype of *C. tetragonoloba* were selected carefully and germinated in Petri-dishes containing moistened filter papers.

2.7.2 Seedling treatment

For treating the seedlings with the electric field, the Petri-dishes were set in the gaps between the plates of the capacitors (Fig. 1). The electric circuit was switched on. One set of Petri-dishes of each genotype was isolated from any electric field and kept as a control. All treated plants were grown under nursery conditions and radicle length was recorded after three days of treatments.

2.8 Experiment 2: - Effect of electric field on the vegetative growth of *C. tetragonoloba*

The experiment was designed to investigate the effect of electric field on the vegetative growth of *C. tetragonoloba*. In this experiment groups A and B were used as described previously within 8 days after treatments.

2.8.1 Seed germination

Seven seeds of the five genotypes of *C. tetragonoloba* were selected carefully and soaked in tap-water for 3-4 hrs. After the emergence of the radicle to about 3-4 mm, the germinating seeds were transferred and planted in black polythene bags (20x30cm) containing a soil mixture of sand and clay at the ratio of 1:1, v/v. The germinating seeds were supplied with sufficient water during the experimental period.

2.8.2 Seedlings treatment

The polythene bags were set in the gaps between the plates of the capacitors (Fig. 1). The electric circuit was switched on.

One experimental set of each genotype was isolated from any electric field and kept as a control. Plant height was measured three times during the first week after treatment.

2.9 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) [9].

3. Results and Discussion

3.1 Experiment 1: - The effect of exposure of *C. tetragonoloba* germinating seeds to electric field

After 3 days of treatments: statistical analysis for group A (Table 1, Fig. 3) show that; all treatments significantly reduced radicle length of the five genotypes when compared with the control plants. Treatment with 9 volts had the highest mean value of reduction. The highest percentage of reduction by 9 volts was 91.5 % in genotype Gm6, and the lowest percentage of reduction was 73.4% in genotype Gm5. Statistical analysis for group B (Table 1) shows that 6 volts significantly reduced radicle length of the genotypes Gm2, Gm6 and Gm8 when compared with control plants. The highest percentage of reduction by 6volts was 74.4 % in genotype Gm2, and the lowest percentage of reduction was 56.9% in genotype Gm6, while radicle length of genotype Gm5 was not significantly increased by 6volts.

Table 1: Radicle length of *C. tetragonoloba* group A and B, 3 days after treatments

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
Treatments	Group A= 25 cm^2						
0 volt (control)	18* (100%)	7.9 (100%)	23.5 (100%)	18.6 (100%)	12.5 (100%)	16.1	6.0
6 volts	6.4 (35.4 %)	3.9 (49.2 %)	10.8 (46%)	2.1 (11.5%)	1.4 (11.2%)	4.9	3.8
9 volts	3 (16.7 %)	2.1 (26.6 %)	2 (8.5%)	4.1 (22.1%)	1.5 (12%)	2.5	1.0
22.1 volts	1 (5.6%)	4.6 (58.2%)	5.9 (25.1%)	1.2 (6.6%)	5. 7 (45.3%)	3.7	2.4
30 volts	7.9 (43.8 %)	3.3 (41.8 %)	7.5 (32%)	1.3 (7%)	4.1 (32.8%)	4.8	2.8
MEAN ± SD	7.3 ± 6.6	4.4 ± 2.2	9.9 ± 8.2	5.5 ± 7.4	5.0 ± 4.6		
	Group B= 225 cm^2						
0 volt	15.6 (100%)	4.1 (100%)	20 (100%)	18. 7 (100%)	17.3 (100%)	15.1	6.4
6 volts	4 (25.6%)	4.2 (103%)	8.6 (43.1%)	4. 9 (26.2%)	5.3 (30.6%)	5.4	1.9
MEAN ± SD	9.81 ± 8.2	4.2 ± 0.1	14.3 ± 8.0	11.8 ± 9.7	11. 3 ± 8.5		

*Mean value of 10 replicates ± S.D.

Okumura *et al.* (2010) [21] 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 length and weight of *Raphanus*, where encouraged the consumption of substances which is stored in the seed of *Raphanus*.

Control seeds germinated towards gravity, while treated seeds with electric field germinated towards sheets of electric field when all seeds were placed on the same level as shown in Fig. 2.

Early in 1927, Navez[19] designed experiments in such a way to eliminate as completely as possible products of polarization and the migration of such products when formed. He showed that the exhibition of galvanotropic curvature in roots is mainly dependent upon such products, since no curvature appeared when they were excluded. Navez (1927) [19] made a reason for this phenomenon, that the polarization products injure the external layer of cells of the root, and this allowed these cells to act as electrodes directly applied on the internal tissues. The inner electrolysis produces such changes in the interior cells that they may be considered as becoming ionically different. This differential state is responsible for curvature. Therefore, Navez (1927) [19] considered that galvanotropism of roots, cannot be regarded as exactly comparable to the galvanotropic orientations of certain animals, but is essentially dependent upon injury.

3.2 Experiment 2: Effect of electric field on the vegetative growth of *C. tetragonoloba*

A | B

Fig. 2: Radicle curvature of treated seeds of *C. tetragonoloba* with electric field
A= Control seeds growing towards gravity, B= treated seeds growing towards electric sheet

After 4 days of treatments statistical analysis for Group A (Table 2) shows that; 9, 22.1 and 30 volts reduced plant height of the five genotypes when compared with control plants. Plants treated with 9 volts had the highest mean value of reduction. The highest percentage of reduction by 9volts was 69% in genotype Gm34 and the lowest percentage of reduction was 42.8% in genotype Gm5. While 9volts significantly enhanced plant height of genotype Gm8 by 78%. Also, 6volts significantly enhanced plant height of the genotypes Gm8 and Gm34 and significantly reduced plant height of the genotype Gm5 by 77.3%.

Statistical analysis for group B (Table 2) shows that 6volts treatment significantly reduced plant height of the five genotypes when compared with control plants (Fig. 3). The highest percentage of reduction by 6volts was 54.3% in genotype Gm5, and the lowest percentage of reduction was 5.6 % in genotype Gm8. Treatment with 6 volts did not significantly enhanced plant height of genotype Gm34.

Table 2: Plant height (mm) of *C. tetragonoloba* Group A and B, 4th day after treatments

Genotypes	**Gm2**	**Gm5**	**Gm6**	**Gm8**	**Gm34**	**MEAN**	**SD**
Treatments	Group A= 25cm^2						
0 volt (control)	11.8* (100%)	35.3 (100%)	27.6 (100%)	14.8 (100%)	14.5 (100%)	20.8	10.1
6 volts	12.8 107.7%	8 22.7%	29.5 107%	21.8 147%	38.7 266.7%	22.1	12.4
9 volts	0	20.2 57.2%	13.2 47.8%	26.4 178%	4.5 31%	12.8	10.9
22.1 volts	14.5 122.5%	16.7 47.2%	15 54.4%	8.8 59.6%	17.3 119%	14.5	3.3
30 volts	14.4 121.7%	18.1 51.4%	20.6 74.6%	14.4 97.3%	9 62.1%	15.3	4.4
Mean ± SD	10.7 ± 6.1	19.7 ± 9.9	21.2 ± 7.3	17.3 ± 6.9	16.8 ± 13.2		
Group B= 225cm^2							
0volt	11.8 (100%)	35.3 (100%)	27.6 (100%)	14.8 (100%)	14.5 (100%)	20.8	10.1
6volt	6.5 54.9%	16.1 45.7%	19.8 71.8%	14 94.4%	26.1 180.3%	16.5	7.3
Mean ± SD	9.2 ± 3.8	25.7 ± 13.5	23.7 ± 5.5	14.4 ± 0.6	20.3 ± 8.2		

*Mean value of 10 replicates ± S.D.

After 6 days of treatments statistical analysis for group A (Table 3) shows that all treatments reduced plant height of the five genotypes when compared with control plants. Nine volts had the highest mean value of reduction. It significantly reduced plant height of the genotypes Gm2, Gm5, Gm6 and Gm34, while 9 volts significantly enhanced plant height of genotype Gm8 by 51.7%.

Table 3 shows that for group B 6 volts significantly reduced plant height of the genotypes Gm2 and Gm5 when compared with control plants, and significantly enhanced plant height of genotypes Gm8 and Gm34. Treatment with 6 volts did not significantly reduce plant height of the genotypes Gm6.

After 8 days of treatments for group A the results presented in Table 4 show that all treatments reduced plant height of the five genotypes when compared with control plants. Nine volts resulted in the highest mean value of reduction. It significantly reduced plant height of the genotypes Gm2, Gm5, Gm6 and Gm34, while 9 volts did not significantly enhance plant height of genotype Gm8.

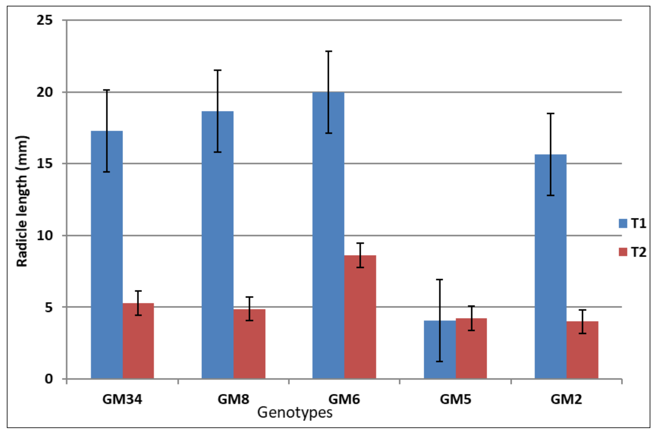

Fig 3: Radicle length (mm) of *C. tetragonoloba* seeds of five genotypes treated with electric field

T1= 0 volt (control), T2= 6 volts

Table 3: Plant height (mm) of *C. tetragonoloba* Group A and B, 6th day after treatments

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	MEAN	SD
Treatments	Group A= 25cm^2						
0 volt (control)	31.8* (100%)	78.9 (100%)	55.7 (100%)	34.8 (100%)	54 (100%)	51.0	19.0
6 volts	46.2 145.1%	27.8 35.2%	61.3 110.1%	51.2 147.1%	48.8 90.4%	47.1	12.2
9 volts	8.7 72.2%	49.3 62.6%	33.7 60.4%	52.8 151.7%	11 20.4%	31.1	20.7
22.1 volts	58 182.2%	33 41.8%	41.5 74.5%	33 84.8%	41.8 77.3%	41.5	10.2
30 volts	48 150.8%	41.3 52.4%	54.2 97.3%	34.1 98.1%	39.7 73.5%	43.5	7.8
MEAN ± SD	38.5 ± 19.1	46.0 ± 20.1	49.3 ± 11.3	41.2 ± 9.9	39.0 ± 16.7		
	Group B= 225cm^2						
0 volt (control)	31.8 (100%)	78.9 (100%)	55.7 (100%)	34.8 (100%)	54 (100%)	51.0	19.0
6 volts	18.3 57.3%	35.4 44.9%	46.5 83.5%	44.8 128.7%	56.9 105.3%	40.4	14.5
Mean ± SD	25.0 ± 9.6	57.1 ± 30.7	51.1 ± 6.5	39.8 ± 7.1	55.4 ± 2.0		

*Mean value of 10 replicates ± S.D.

For group B Table 4 shows that 6 volts significantly reduced plant height of the genotypes Gm2, Gm5, Gm6 and Gm8 when compared with control plants, while 6 volts significantly enhanced plant height of the genotype Gm34 by 11.1%, over the control plants.

According to Karez and Burdach (1995) [13] 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.

Fig. 4 showed that 6 volts reduced plant height of genotype

Gm6 when compared with control plant.

Table 4: Plant height (mm) of *C. tetragonoloba* Group A and B, 8th day after treatments

Genotypes	Gm2	Gm5	Gm6	Gm8	Gm34	Mean	SD
Treatments	Group A= 25cm^2						
0 volt (control)	49.5* (100%)	89.4 (100%)	75.7 (100%)	61.7 (100%)	62 (100%)	67.7	15.3
6 volts	57.6 116.4%	45 50.3%	58.8 77.8%	79 128.1%	74.3 119.8%	62.9	13.7
9 volts	12.3 24.4%	61 68.2%	53 70%	64 103.8%	15 24.2%	41.1	25.4
22.1 volts	69 139.4%	52.8 59.1%	50.5 66.7%	43.2 70.1%	61.3 98.9%	55.4	10.0
30 volts	64 129.3%	39.3 43.9%	64.2 84.8%	56 90.8%	70.3 113.3%	58.7	12.0
MEAN ± SD	50.5 ± 22.6	57.5 ± 19.6	60.4 ± 10.0	60.8 ± 13.0	56.6 ± 23.9		
	Group B= 225cm^2						
0 volt (control)	49.5 (100%)	89.4 (100%)	75.7 (100%)	61.7 (100%)	62 (100%)	67.7	15.3
6 volts	16.2 32.7%	57.3 64.1%	67.3 89%	58.8 95.3%	68.9 111.1%	53.7	21.6
MEAN ± SD	32.8 ± 23.6	73.4 ± 22.7	71.5 ± 5.9	60.2 ± 2.1	65.4 ± 4.8		

*Mean value of 10 replicates ±

T2 T1

Fig. 4: Treated *C. tetragonoloba* genotype Gm6, group A, 12th day after treatments
T1= 0 volt (control), T2= 6 volts, Group A= 25cm^2 plates area

4. Conclusion

It was concluded that the five genotypes of *C. tetragonoloba* have responded differently to the exposure of electric field doses at different voltage levels.

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6. References

1. Behrens HM, Weisenseel MH, Sievers A. Rapid changes in the pattern of electric current around the root tip of *Lipidium sativum* L. following gravistimulation. Plant Physiol. 1982; 70:1079-1083.
2. Brayman AA, Miller MW. Proportionality of 60-Hz electric field bioeffect severity to average induced transmembrane potential magnitude in a root model system. Radiat Res. 1989; 117(2):207-213.
3. Brunchorst J. Bet. bot. Ges., ii, 204; Bot. Centr. 1884. xxiii, 192; 1889, Bergens Museums Aarsberetining, Bergen, 1885.
4. Elfving F, Bot Z xl. 257, 273; Bot. Centr. 1882, 12:362.
5. El-Tahir BA. Effect of electric field on growth and development of *Vicia faba* L. plant. M.Sc. thesis. Botany. University of Khartoum, 2011.
6. El-Tahir BA. Effect of electric field on growth and development of five genotypes of *Cyamopsis tetragonoloba* L. plant. Ph.D. thesis. Botany. University of Khartoum, 2017.
7. Ewart AJ and Bayliss JS. Proc. Roy. Soc. London, Series B, 1906, Ixxvii:63.
8. Gassner G. Bot Z, lxiv, 149; 1907. Zur Frage der Elektrokultur. Ber. dtsch Bot. Ges. 1906; 25:26-38. Bet. bot. Ges., xxv, 26.
9. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. John Wiley, NY, 1984.
10. Hart FX, Schottenfeld RS. Evaporation and plant damage in electric fields, Int. J. Biometeorol. 1979; 23(1):63-68.
11. Inoue M, Miller MW, Carstensen EL, Brayman AA. The relationship between sensitivity to 60-Hz electric fields and induced transmembrane potentials in plants root cells. Rad. Environ. Biophy. 1985; 24(4):303-314.
12. Inoue M, Miller MW, Cox C, Carstesen EL. Growth rate and mitotic index analysis of *Vicia faba* L. roots exposed to 60- Hz electric fields. Bioelectromagnetics. 2005; 6(3):293-303.
13. Karez W, Burdach Z. The effects of electric field on the growth of intact seedlings and coleoptile segments of *Zea mays* L. Biol. Plant. 1995; 37(3):391-397.
14. Kiatgamjorn P, Khan-ngern W, Nitta S. The effect of electric field on bean sprout growing. ICEMC. Fac. Eng. K. M. Ins. Techn. Ladkrabang Bangkok, Thialand. Igusa Suginami Tokyo, Japan, 2002.
15. Miller MW, Dooley DA, Cox C, Carstensen EL. On the mechanism of 60-Hz electric field induced effects in *Pisum sativum* L. roots: vertical field exposures. Radiat. Environ. Biophys. 1983; 22(4):293-302.
16. Müller-Hettlingen J. Arch. ges. physiol. 1883. xxxi, 193.
17. Murr LE. Plant growth response in a simulated electric field – environment. Letters to Nature. 1963; 200:(490-491). Depart. Engineer Mechanics, Pennsylvania State University, U. Park, Pens. Nature publishing group USA.
18. Murr LE. Physiological stimulation of plants using delayed and regulted electric field environments. Inter. J. Biometeor. 1966; 10(2):147-153. De. En. M., Pen. S. U., U. P., Pen. USA.
19. Navez AE. Galvanotropism of roots. J Gen. Physiol. 1927. Harvard University, Cambridge.

20. Nechitailo G, Gordeev A. The use of an electric field in increasing the resistance of plants to the action of unfavorable space flight factors. Science Direct – Advances in Space Research. Institute of Bioch. Phy., Moscow, Russia. Agricu. Ins., Smolensk, Russia, 2004.
21. Okumura T, Muramoto Y, Shimizu N. Acceleration of plant growth by D.C. electric field. Solid Dielectrics (ICSD), IEEE International conference. Potsdam. 2010; P:(1-4).
22. Portier CJ, Wolfe MS. Assessement of Health Effects from Exposure to power-Line Frequency Electric and Magnetic Fields. Working group; The United State Department of Energy and the National Institue of Environmental Health Sciences (NIEHS)/ National Institute of Health, 1998.
23. Rajendra P, Nayak HS, Sashidhar RB, Subramanyam C, Devendranath D, Gunasekaran B. *et al*. Effects of power frequency electromagnetic fields on growth of germinating *Vicia faba* L., The Broad Bean. Electromagnetic Biology and Medicine. 2005; 24(1):39-54
24. Rischawi L. Bot. Centro, 1885, xxii:121.
25. Robertson D, Miller MW, Cox C, Davis HT. Inhibition and recovery of growth processes in roots of *Pisum sativum* L. exposed to 60-Hz electric fields. Bioelectromagnetics. 1981; 2(4):329-340.
26. Schellenberg H. Flora, 1906, xcvi:474.
27. Stern KR. Electrophysiologie der pflanzen, Monographien aus derm Gesamtgebiet der physiologie der pflanzen und der Tiere, Berlin, iv, 1924.
28. Stern KR. Introductory Plant Biology, 5th Edition. Dubuque, Iowa: William C. Brown Publishers, 1991.
29. Szücs J. Jahrb. Wissensch. Bot. 1913; Iii:326-327.