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Impact of Electric and Magnetic Field Exposure on Young Plants-A Review

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A B S T R A C T

Wide range of experiments was done on the impact of externally applied electric and magnetic field upon plants. From ancient time to new age the new technologies has invented and the researches on this topic was enhanced. This paper highlights the results of the investigations starting from 1746.

Introduction

The surface of Earth, the atmosphere and the ionosphere consists of the global atmospheric electrical circuit (Wilson, 1906) and for plant growth the natural electrical field which is a few ten of V/m is essential (Wheaton, 1970). Electromagnetic energy in the visible range has long been known as an important factor for photosynthesis (Borthwick, 1965) and also needed for plant processes viz photoperiodism and germination. Plant food in the forms of flow of sap is carried out through all the rootlets, center, in the stalks to the proper sites due to electricity. The term “electroculture” was used in ancient times to increase the growth and yield of crops through the electrical treatment, such as electrical charged network over the plants or an electric current

through the soil by which the plants are growing. The effect of electric current on the growth characteristics has been started with the work of Dr. Maimbray in 1746 (Solly, 1845). However first attempt to apply electric field on crops was done by Berthelon in 1870. Basty and Sanborn got positive results on plant yield by applying modified atmospheric electricity whereas Solly found no appreciable change (Basty1908, and Sanborn1893).

Both electrical and electromagnetic energy are essential components of plant life. Electrostatic fields of varying intensities have applied on plants under both laboratory and field conditions for more than 250 years but optimum conditions could not be

confirmed for commercial benefits due to various types of outcomes. This paper is an attempt to highlight the results of

experiments on the growth of plants using electromagnetic field.

Table.1 The Chronological Survey of Plant Growth Under Electric Field

Year	Events	References
1746	First evidence of electricity applied on plant growth was found by Dr. Maimbray.	Dorchester, 1937
1775	Beccaria told that electrical currents may influence the vegetation.	G. Beccaria 1775
1783	The increased growth and fertility was observed under the influence of electricity by Berthelon after the discovery of electricity in atmosphere.	Benjamin Franklin 1783, Bertholon M. 1783
1840	The growth of potato plants was enhanced by using galvanic cell buried in the field.	Ross, W. 1844
1845	Solly carried out a series of tests with different crops by inserting 4/5 inches electrodes into soil and both positive and negative results were obtained. Similar experiments were carried over the globe.	Solly 1845, Maccagno 1880, Paulin 1892, Wollny 1893, Basty 1908
1878	Dependence of atmospheric electricity on the growth of tobacco, corn and wheat were investigated by Grandeau	Grandeau 1878
1880	Lemstrom noted the rapid growth of trees due to the event of Aurora Borealis	Lemström 1904
1881	The roots of different seedlings between two electrodes were found to curve towards the positive pole.	Elfving, F. 1882
1884	Increased growth sugar beets using copper electrodes was reported	Holdefleiss 1885
1889	Fresh weight of plants grew under network were more than control as observed by Berthelot after the first installation of 21km AC transmission line at U.S. in 1889 trialed with soil currents and found the plants.	Berthelot 1889 Rustebakke 1983
1898	Grandeau investigated the effect of atmospheric electricity on plants by covering the field with a net. The uncovered plants grew 50-60% higher than the shielded plants.	G. Stone 1904
1900	The long distance and rapid electrical signaling was reported to stimulate leaf movements in <i>Mimosa</i> and <i>Desmodium</i> producing continuous and systemic electrical pulses as obtained by Sir J.C. Bose.	J. C. Bose 1918
1904	Increased yield (22% to 58%) of radish and lettuce plants were obtained after the treatment of plants by 0.2 to 0.4mA current.	Stone, 1904, Charles S. Dorchester 1937
1907	Electrically charged soil has unfavorable action upon plant growth according to Gassner. Plant-electrical activity was investigated by several scientists all over the globe.	Bose 1907, Gassner 1907, 1909, Brauner 1927, Clark 1937 Schrank 1947
1909	Soil bacteria was increased up to 600% if a few sparks of static electricity was discharged into the soil every day.	G. Stone 1909
1912	Plant growth were noticed using geomagnetifier by Kovessi and other investigators.	Kovessi 1912
1915	The Lodge-Newman apparatus was used for plants by Jorgenson after the application of induction coil by Newman in agricultural field	Newman 1922
1920	Curtis used a Tesla coil of 10 kV/500 W to supply high tension current over 200 sq. ft area covered with radishes and lettuce. 50% enhanced growth was the result.	Paleg 1932
1924	No significant change of soil nitrogen after the application of electric field to oats was noticed Lakhovsky introduced the oscillator circuit, a one-turn copper coil. Oscillating currents produced was beneficial to plant.	Blackman 1924 Lakhovsky 1939
1929	Lund observed the relative potential of the growing points of the douglas fir tree and found the apical leader of the tree had a (+) charge.	Lund 1929(a), 1929 (b)

1930	Christofleau experimented on field with the electromagnetic fertilizer and antennas for agricultural improvement.	Christofleau Justin 1930
1934	Osterhouse observed the electrical variation across the membrane of <i>Nitella sp.</i> by the electrode in the cell and the Na ⁺ flowed into and K ⁺ flowed out.	Gary J. Lockhart 2009
1937	Cholodny and Sankewitsch used oat coleoptiles with 10 ⁷ - 10 ⁶ amp currents and growth was observed.	Cholodny and Sankewitsch 1937
1937	Board of Agriculture and Fisheries, U.K. after 18 years of investigations was not sure about the benefits of electrical treatment on crops	Board of Agriculture and Fisheries Report 1937
1938	A number of studies were carried out on the effect of electrostatic field and possibilities of lethal electro tropism was assumed by the impact of higher electric field.	Miller 1938, Shlanta and Moore 1972
1947	Lund explained that electrical potential exists in plant root.	Lund, E. J. 1947
1957	In a sealed tube an electrode of 60 cycles/s containing corn seeds showed an increased germination rate.	Brown 1957
1962	Pratt tested black mustard seedlings with air ions and shoot length increased. Krueger, Kotaka and Andriese observed the effect of (+) and (-) air ions on the accelerated plant growth. Air ions are the principal mediating agent in electroculture was reported by Kruger, Kotaka and Andries.	PrattR. 1962, Krueger Kotaka and Andriese 1962, 1964, Krueger <i>et al.</i> 1978
1964	Murr experimented by applied electric fields major changes in several trace element levels was affected.	Murr, 1964,1965
1965	The bioelectric potentials around the roots of <i>Zeamaiz</i> play an important role was illustrated by Larson. Anderson and Vad reported the inhibition of bacterial growth occurred by the 3 kV/cm electric fields.	Larson 1965 Anderson and Vad 1965
1966	Keller treated avocado affected with canker and orange trees with scaly bark by inserting electrode. New shoots appeared and after the bark removed, the trees began to bear fruit.	Keller 1966
1968	Kotaka and Krueger showed that respiration and growth of young barley plants had increased with the increase of air ion density.	Kotaka, S. and Krueger, A.P. 1968, Krueger 1978
1970	Andrew Zaderaj and Claude Corson invented Electrogenic Seed Treatment	Zaderej A. and Corson 1970
1972	Black applied 3 - 15 A by electrodes into tomato plants and observed linear increase of growth. Kotaka and Kruger noted the effect of air ions on RNAase activity in barley leave. Burr used voltmeter and measured differences in electrical potentials of plants.	Black 1971, Kotaka and Krueger 1972, Burr HS. 1972
1973	Higinbothamwitnessed electro potentials affected by electric field and the pathway in cells.	Higinbotham 1973
1975	Hodges observed the effect of 765 kV transmission line on the growth of crops.	Hodges 1975
1977	Decrease in fresh weight of <i>Hordeum vulgare</i> seedlings by using magnetic field treatment of 10 nT whereas increase in fresh weight of <i>Helianthus annus</i> seedlings were noticed by using magnetic field treatment of 20μT in 2004	Lebedovet <i>al</i> 1977, Fischer <i>et al</i> 2004
1978	Genotoxic and cytotoxic effects on different plant species was observed to occur by electric, magnetic and electromagnetic field and increased percentage of chromosomal aberrations was reported.	Linskens 1978, Ellis 1978, Mamata 1987, Saxena 1987, Runthala 1991, Promila 1991, Zaidi 2003, Pavel 2005, Hanafy <i>et al.</i> 2006, Zhang <i>et al</i> 2007
1979	Deep green leaves treated by electrostatic field was attributed to enhancement of porphyrin. The leaves of pole beans become darker after exposed to electrostatic field of 20μA for five hours was noticed by Hart and Schottenfield. Similar results were also reported by several investigators	Hart and Schottenfield 1979

1985	Electric field effect on calcium and auxin transport in plant were observed.	Hepler and Wayne 1985, Rathore and Goldsworthy 1985
1988	EMF may cause changes of gene expression, cell reproduction, enzyme activity, protein biosynthesis, oxidative stress and cellular metabolism	Tsong 1988, Woodward 1990, 1991, Sen Gupta <i>et al.</i> 1993, Astumian, R. D. 1993, 1998, Tkalec 2005
1989	The electric current flows along the surface of upright-growing epicotyls.	Tokoet <i>al</i> 1989, 1990
1991	The external electric field can modify the direction of growth of pollen tubes and roots of plants.	Nakamura 1991, Wolverson2000, Kalinina 2010
1992	The development of lateral roots of plants were affected by electric fields.	Hamada <i>et al</i> 1992
1995	ELM treatment has significant effect on the generated polymorphisms in plant genome After precipitation the plant's nutrient uptake also enhances and the calcium influx, metabolic activity also increased.	Goodman 1995, Karcz and Burdach 1995, Seyedet <i>al</i> 2014
1996	Platzeret <i>al</i> observed increased H _b -ATP ases by electric field leads an enhanced lily pollen tube growth.	Goldsworthy, 1996, Platzeret <i>al.</i> 1997
1997	Electric field inhibited the biological properties of the membrane protein.	Pakhmova 1997, Walter 1997, Labarge 1998
2001	Electric shock on wheat and barley showed significant variation in several traits, grain yield and protein percentage.	Elsahookie2001, Nechitailo and Gordeev 2001
2002	Germination and growth rate of maize and different fruit seedlings are increased by the treatment of magnetic field	Martinez <i>et al</i> 2002, Yan <i>et al</i> 2009
2003	4 kv/m electrostatic fields has showed positive response to free radicals in seeds. 66-220 kV has the tendency to produce diads and diploid pollen grains.	Bai <i>et al</i> 2003, Zaidi and Khatoon 2003
2004	Fisher observed the effect of magnetic field of railway traction on the root and shoot growth of young sunflower plants	Fischer 2004
2007	Suitable combination of magnetic field and exposure time could give <i>Helianthus annuus</i> yields	Florez 2007, Vashisth 2010
2008	Proline accumulation may be induced by the stress of electromagnetic radiation in plants.	Verbruggen, N. and C. Hermans. 2008
2009	The synthesis of DNA and RNA and the cell proliferation affected by the magnetic field due to the cellular stress response. In another experiment Scopa <i>et al</i> found considerable increase of root and shoot growth of <i>Arundodonax</i> young plant when exposed to 12.0 v/m DC electric field. Under similar condition of electric field it was observed that root growth of tomato seedlings were affected by the positions of plants between the electrodes.	Ruediger HWR 2009 Scopa <i>et al</i> 2009, Tataranniet <i>al</i> 2013
2010	The increasing genetic diversity of individual wheat plants by the effect of HVTL was detected. The effect of HVTL on growth of leylandi seedlings was observed. The chromosome aberration by the effect of 380 kV was noticed.	Bakatoushi, R. E., 2010, Demir 2010, Aksoy 2010
2011	Suitable combination of geomagnetic and magnetic fields may enhance the seedling growth	Hajnorouziaet <i>al</i> 2011
2011	Hasan <i>et al</i> observed the negative growth of Maize plants under 400kV. Seeds were pretreated with 3 and 10 mT for 4 h and mitotic analysis was done. Chromosomal aberration was increased in 10 mT	Hasan <i>et al</i> 2011, Shabrangi 2011

2012	Maziahet <i>al</i> after investigating the impact of power line over mustard agriculture field suggested that electromagnetic field can be used to enhance the growth of plants.	Maziahet <i>al</i> 2012
2013	The effect of electric fields on growth characteristics of onion seedling was studied	ForoughMolamofrada 2013
2013	Treatment of EMF on tomato (<i>Solanunlycopersicum</i>) okra (<i>Abelmoschuseculentus</i>) and eggplant (<i>Solanum melongena</i>) has increased the susceptibility of the plants to pests and insects but have mixed result to their growth characteristics	Rio and Rio 2013
2014	Application of 50mV increased the saccharification efficiency of 25% higher than 60mV enzyme damaged. Growth rate decreased with the increase of electric field Geomagnetic field has effect on plant growth The application of electrostatic field, microwave irradiation and corona discharge methods had a prominent impact on seed germination.	Nadia <i>et al</i> 2014, Ghorai 2014, M. E Maffei 2014 WamanZibljajiGandhare 2014
2014	0.8 mT in 5 minutes duration and 1.6mT in 10 minutes duration exposure of <i>Urticadioica</i> L showed the fastest germination	Rostamizadeh E. 2014
2015	By applying electromagnetic field improvement in germination rates, growth of coleoptiles and decrease in the time of dormancy can be done High power transmission lines affects the growth of plants in agricultural and forest lands near high power transmission lines. The geomagnetic field most probably influences trees through variations of the atmospheric electric field. This is a secondary order effect	Jannet Ortiz Aguilar 2015 Balaji, A. 2015, O. Khabarova,2015

Conclusion

From the review it can be concluded that electric/magnetic/electromagnetic exposure have the possibilities to increase the productivity but the optimum conditions are differed from crop to crop under varied climatic conditions. The electromagnetic field has some stress factors on plants as reported by many observers over the globe. More researches are needed to overcome stresses in agriculture production using electric field.

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