ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, Januray 2016

# Environmental Impacts of Electromagnetic Radiation Inducted by High Voltage-Power Lines

Fatima M. Z. Alaish[1], Hassan S. M. Al-Zahrani[1] and Sherif S. Z. Hindi[2]

Department of Biology, Faculty of Science. King Abdullaziz University, Saudi Arabia[1]

Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture. King Abdullaziz University, Saudi Arabia[2].

**ABSTRACT**:Electricity generated from power plants is usually sent over long distances through overhead power transmission lines with high-voltage wires that generate electromagnetic field (EMF) around them. Since living organisms generate and conduct electrochemical impulses through their different tissues and organs it may affected by the EMF. The mechanism of this interference between EMF and plant as well as human tissues is not clearly understood.

Studying plant behavior under low EMF by some researchers revealed that these circumstances can affect plant growth. In addition, other researchers have found that weak EMF suppressed this growth, reduced cell division, intensified protein synthesis and/or cause disintegration in plant roots. On the other hand, other studies found an increase in plant growth such as enhancing seed growth for some species. The inconsistency and contradictory outcomes from the studies appear to indicate that the effects of EMF on plants may be dependent on species and/or EMF characteristics such as intensity and duration. While it is difficult to avoid all EMF radiation, certain precautions can be taken to avoid EMF radiation. Determining and avoiding the highest emitting items is crucial for general health. Additional steps that can be taken to avoid radiation include purchasing and running an aquarium in the home to absorb microwave energy, limiting mobile phone use and using a wired internet connection that is safer than the wireless one.

**KEYWORDS**:*Keywords:* Electromagnetic field; High voltage tower lines; plant growth

## I. INTRODUCTION

The Kingdom of Saudi Arabia comprises an area of 2.25 million km$^2$, encompassing vast deserts, rugged mountains, coastal cities, villages, and settlements. The country is the fastest growing electricity consumer in the Middle East. Electricity consumption in the Kingdom was increased sharply during the 1990–2010 period due to rapid economic development. The total amount of energy produced by the Saudi Electricity Company in 2013 is about 198,900 GWH (Annonymous[b&c], 2013 and 2014, respectively). Production capacity is planned to be increased up to 120 GW by 2020.

### Electromagnetic field (EMF)

There are different natural sources of electric, magnetic and electromagnetic fields on Earth which act on organisms. Besides, man has created other sources of electromagnetic fields in his environment which differ in their frequency and intensity.

The EMF consists of an electrical part and a magnetic part. The electrical part is produced by a voltage gradient and is measured in volts/meter. The magnetic part is generated by any flow of current and is measured in tesla. Shawanroy (2012) presented that EMF can be viewed as the combination of an electric field and a magnetic field. Electric field is produced by stationary charges, and the magnetic field by moving charges (current).Electro-Magnetic Field strength is measured in Ampere per meter (A/m). EMF researchers and investigators use a related measure, flux density, in microtesla (µT) or millitesla (mT) instead. Both types of fields give biological effects, but the magnetic field is more damaging since it penetrates living tissues more easily. Magnetic fields as low as around one microtesla can produce

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 1, Januray 2016**

biological effects. The electric current along a coiled-wire or conductor formed into an inductor produces an EMF. It exists when there is a current flowing along a conductor and its strength increases as soon a device like an inductor or a coiled-wire is switched on and current moves through it (RamezaniVishki, 2012[a&b]). The magnetic field becomes stronger when there is greater electricity flow. According to Somasekaran (2007) one of the sources of producing EMF is the high power transmission lines. The High voltage means electrical energy at high voltages which is sufficient to cause harm or death upon living things. High voltage is used in several applications like electric power distribution, cathode ray tube to generate X-rays, particle beams, vacuum tubes, manufacturing and scientific applications.

**Transmission lines system in Saudi Arabia**

The high voltage direct current transmission lines (HVDC) is a high power electronics technology used in electric power systems mainly due to its capability of transmitting large amount of power over long distances (Sood, 2004). The HVDC technology was used in the Kingdom for the first time in 1954. The rapidly growing economy of the Kingdom is critically dependent on the performance of its transmission system and facilities. So far, the Kingdom has a power transmission network that spans around 38,000 circuit km of high voltage lines and cables and range from 110kV to 380kV. This network is operated by Saudi Electricity Company and managed by Transmission Business Unit (TBU) with the help of 570 substations and 1653 power transformers which have capacity of well over 148,088 MVA In addition, The voltage level of high power transmission lines are 400 KV, 230 KV, 110 KV, 66 KV, etc. The voltage existing between each wire transmission tower is 380kV, all towers height is between 65-75 meters and there are 24 conductors in each face in the tower. Most of the areas in agricultural and forest lands in the Kingdom of Saudi Arabia are situated in the area where high power transmission lines pass (Annonymous[b], 2013).

**Effects of EMF on plant health**

Limited information on the effect of EMF on plants is available. Most researchers focus on strategic crop plants leaving a knowledge gap on other species such as wild plants. Considering possible consequences, including economic and ecological impacts, more work is needed to clarify the basics of biological effects by electromagnetic fields.

Modern civilization depends heavily on the widespread use of high voltage transmission lines for industrial, agricultural, and domestic purposes. This has enhanced the exposure to the EMF that has adverse biological effects on living organisms. Plants play an important role in the living world as main producers of food and oxygen; therefore, it would be beneficial to examine their relations with today's increased exposure to electromagnetic fields.

All living organisms generate and conduct electrochemical impulses all the way through their different tissues and organs. Properties of temperature sensing in plants has been demonstrated experimentally (Plieth, 1999). The EMF from high power transmission lines affects the growth of plants. Extensive biological, geological, and oceanographic researches has been carried out to investigate the effects of high voltage fields on the environment (Cherry, 2001; and Demir, 2010). In electrical power transmission engineering high voltage is usually considered as any voltage above 35 KV. The voltage of these magnitudes can affect the plant in one way or the other as the most vital physical signal in any organism is electrical signal. In comparison to chemical signals (e.g. hormones) the electrical signal is able to transmit signals more rapidly over long distances.

Recently, biologists have revealed that electrical signals are significant in many physiological activities of plants. The electrical signaling in fruit trees in response to water and darkness conditions was studied by Trebacz*et al.*, (2006), Gurovich, and Hermosilla (2009) and Paul *etal.*, (2006). In addition, Desrosiers and Bandurski, (1988) investigated the effect of longitudinally applied voltage on the growth of *Zea Mays* seedlings. Electrical signals are involved in many processes in plants life including respiration, water uptake, and leaves movements (Fromm and Lautner, 2007). Various changes regarding to plant growth parameters such as meristematic activities, cell differentiation, shoot length, root length, leaf area, specific leaf weight, total biomass content, total water content, chlorophyll, carotenoids, soluble sugar, soluble starch, soluble protein content, biochemical, and antioxidant system has been shown to be affected by environmental electric and magnetic fields (Walter *et al*., 1997; Hanafy*et al*., 2006; and Fromm and Lautner, 2007).

The electric field treatment has also been used to control invasive plants by affecting their tissues. It can be also used for allowing and avoiding many undesirable changes in products, pigments, vitamins, and flavoring agents, which are typical for other pre-treatment techniques, including thermal, chemical, and enzymatic ones. Electric field treatment is also capable of microbial inactivation (Vorobiev and Lebovka, 2008). As the resistance of the plant tissue varies considerably from plant to plant, hence, a clear idea of plant tissue electrical properties is essential for the assessment

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 1, Januray 2016**

of its health status. The effect of high voltage at high frequencies may be more significant as compared to low frequency fields.

**Effect of EMF on leaf area**

Noguse*et al*., (1998) and Yao *et al*., (2006) have reported that EMF significantly decreased leaf area in the exposed plants. Reduction of leaf area under EMF radiation is a photomorphogenic response that can limit the damage to leaf tissue caused by radiation (Jansen, 1998). Reduction of leaf area is a response to reduce extent of cell division and elongation. EMF radiation decreased the proportion of mitotically active cells and increased the time taken for cell division (Hopkins, 2002). Rate of fresh and dry weight and leaf area in irradiation samples significantly decreased in comparison with control. The possible reason for reduction of fresh and dry biomass weight might be due to reduction of the leaf area (Noguse *et al*., 1998).

Freeman *et al*., (1999) have found that leaves of soybeans grown under high-voltage transmission lines had greater fluctuating asymmetry than those grown 100 m away. Plant leaves move both diurnally and as they grow leaf orientation toward the EMFs likely changes both diurnally and throughout leaf development. Thus, it is quite likely that the two sides of a leaf may not have experienced the same electromagnetic field strengths. This may partially explain the asymmetry that was observed in soybean leaves. Nevertheless, the mechanism by which EMFs impact symmetry is unknown, but it is possible that the EMFs may have affected internal cell oscillators and/or some aspect of cell signaling. These factors are epigenetic, and this is precisely the type of disruption that Graham *et al*., (1993) and Emlen*et al*., (1993) predicted would cause asymmetry.

**Effect of EMF on chlorophyll content**

Chlorophyll a is the most important assimilatory pigment involved directly in the conversion of solar energy into chemical energy at the molecular level, thus chlorophyll content is an indicator of plant health and productivity. Previous studies showed that photosynthetic pigments may increase or decrease under MF conditions. Chloroplasts have paramagnetic properties which means that magnetic field of magnetic moments of atoms in them are affected by MF and oriented downwards the field direction (Campbell, 1977). Moreover, EMF has an effect over photochemical activity, for example, the rate of $CO_2$ uptake in radish (*Raphanussativus L.)* was reduced following exposure to MF (Yano *et al*., 2004).

Racuciu *et al*., (2008) reported that long MF exposure has the ability to increase assimilatory pigments. This fact was confirmed by several studies for different plants; where MF treatment increased the chlorophyll content in sugar beet (*Beta vulgaris L.*) leaves (Rochalska, 2005) and content of chlorophyll a, b and carotenoids in potato (*Solanum tuberosum* L ( Rakosy, 2005). Additionally, studies by Atak*et al*., (2003) and Atak *et al*., (2007) involving MF impact on soybean (*Glycine max L.)* confirmed that MF significantly increased chlorophyll a, chlorophyll b and total chlorophyll contents.

Study conducted by Atak *et al*., (2003), reported that MF short exposure is accompanied with increases in chlorophyll a, chlorophyll b and total chlorophyll contents. In contrast, longer exposure decreased the level of photosynthetic pigments in *Zea mays L.* (Racuciu*et al*., 2007) and *Robiniapseudoacacia L.* seedlings (Racuciu*et al*., 2008).Taia*et al*., (2007) reported that; Photosynthetic pigments decreases could be due to the effect of MF on the reduction in plastids inside the cells. The reduction of pigments explained by Commoner *et al*., (1956), that chemical with unpaired electrons possess a magnetic moment which plays an important role in electron transfer and kinetics of chemical reactions. The electrons with magnetic moments can be oriented in the external MF. As a result of the interaction between the external MF and the magnetic moment of unpaired electrons, the energy is absorbed. Chloroplasts have magnetic moments and could be affected by the absorbed energy at a high dose of MF which can disturb the pigments synthesis. Dhawi and Al-Khayri (2008) reported that short exposure to alternating magnetic field had a positive impact, whereas long exposure had a negative effect on pigments content similar to MF effect on proline.

**Mechanism of EMF effects on plants**

EMF has magnetic and electrical properties that surround objects with an electrical charge which will interact with other objects within that field. Electrical fields result from the strength (voltage) of the charge and magnetic fields result from the motion (amperage) of the charge. The fields exist with varying strength and degrees, and wavelength and frequency will determine how it behaves.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, Januray 2016

The impacts of EMFs on plants is a question being explored since plants are just as readily exposed to low-level magnetic fields as humans as a consequence of power lines and other industrial technology (Martinez *et* al., 2004). It appears that a magnetic field does have an effect on the growth of plants. Belyavskaya (2004) found that weak electromagnetic fields suppressed the growth of plants, reduced cell division, intensified protein synthesis and cause disintegration in plant roots. Conversely, other studies such as those of RamezaniVishki*et al.*, (2012[a&b]) found an increase in plant growth while other studies like those of Davies (1996) found some seeds increased in growth and others showed no change.

Despite the variable results from different researches, one thing that is not well understood is how magnetic fields affect plants. One of the proposed mechanisms is related to the levels of calcium ions within plant cells. It is found that exposure to weak EMFs remove calcium ions from cell membranes influencing calcium availability and thereby affecting plant processes and ability to respond to stress (Pazur*et al.*, 2006). Researchers like RamezaniVishki*et al.*, (2012[a&b]) suggest that the intensification of growth is due to the increasing of metabolism in irradiated seeds. The leakage of calcium ions into the cytosol (the main part of the cell) acts as a metabolic stimulant, which accounts for the reported accelerations of plant growth (Goldsworthy, 2007), hypothesizes that the loss of calcium ions from cell membranes is the reason why weak fields are more effective than strong ones, why low frequencies such as 16 Hz are more potent and why pulsed fields do more damage. Another proposed mechanism is geotaxis, a phenomenon where magnetic fields will affect cellular organelles such as amyloplasts and influence the direction of plant growth (Peňuelas*et al.,* 2004).

Literature supports that weak EMFs interfere with plant physiology but the mechanisms are not clear. The inconsistency and contradictory outcomes from the studies appear to indicate that the effects of magnetic fields on plants may be species-specific and/or is dependent on the characteristics of field exposure such as intensity and duration. Researches of the effects EMFs on plants are relatively new and information is still limited. Most research focuses on agriculturally important plants leaving a knowledge gap on other species such as algae. Considering possible consequences, including economic and ecological impacts, more work is needed to clarify the basics of biological effects by electromagnetic fields.

The possible effect of electric current upon the growth of plants has been the object of various types of research for more than 150 years. In recent years many phases of this problem have been studied by English, French, Finnish, German and American observers and scientists. A number of them have reported apparent significant increases in crop yields resulting from treatment with electric current; others have found little or no difference. Among these later trials, which, in most instances, appear to have been conducted under carefully controlled conditions, the majority show significant yield increases for the electrical treatment. In the few experiments where the effect of electric current upon the physiologic functions of plants has been investigated, the results obtained have failed to provide a satisfactory explanation for yield differences, therefore, field study of high voltage on natural vegetation is highly required.

Most of the recent studies focus on the growth of plants and the germination of their seeds.According to some studies these fields exerts beneficial effects as it increases rate of growth and early germination of seeds (Florez*et al.*, 2004; Dardeniz*et al.*, 2006; Liang *et al.*, 2009). On the other hand, some studies suggested harmful effects like inhibition of growth and seed germination (Apasheva*et al.*, 2006; Ahmad *et al.*, 2007). In fact, EMF causes an oxidative stress that increases the activity, concentration and lifetime of free radicals (Tkalec *et al.*, 2005). EMF alters protein biosynthesis, enzyme activity, cell reproduction and cellular metabolism (Nirmala and Rao, 1996). Exposure to EMF leads to cell death as a result of increase in free oxygen radicals and DNA damage (Ivancsits*et al*., 2003). Several studies have been conducted to find out the effect of EMF on the growth and physiology of the plants (Yao *et al*., 2006; Shabrangi and Majd, 2009), such as studying effects of EMF on seeds germination and seedlings growth and seed vigor (Moon and Chung, 2000 and Phirke*etal*., 1996).

Plants produce a high diversity of secondary metabolites and antioxidant defense with a prominent function in the protection against stresses on the basis of their defense reactions. Secondary metabolites are to be involved in plant chemical defense systems. High concentrations of secondary metabolites for example phenols and flavonoids might result in a more resistant plant (Wuyts*et al*., 2006). Electromagnetic radiation stress induces proline accumulation in plants (Verbruggen and Hermans, 2008; Kostal*et al*., 2011). Proline accumulation is believed to be very important as part of the physiological adaptation of plants to stress (Siripornadulsil*et al*., 2002).

There is highly occurrence and diversity of many wild plant species occupying the arid land, among which *Calotropis procera* is that known as medicinal plant. *Calotropis procera* is a species of flowering plant in

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 1, Januray 2016**

the dogbane family, apocynaceae, that is native to North Africa, Tropical Africa, Western Asia, South Asia, and Indochina. Common names for the plant include apple of Sodom (Upadhyay, 2014) or milkweed (Hindi, 2013 and 2014). The distribution of *Calotropis procera* is covering most of the desert and semi desert areas, including underneath of the power transmission lines. An attempt to find out the main consequence of high voltage transmission lines on natural vegetation with emphasis on *Calotropis procera* shrubs in Makkah region was made by Alaish*et al*. (2014) to fill the gap concerning to the consequence of high voltage of EMF in natural vegetation.

Previous studies have evidence that low frequency electromagnetic radiation caused abiotic stress on the growth parameters and activity of defense mechanisms of some plants. Consequently, high voltage of electromagnetic field is expected to have some effects on plant growth. *Calotropis procera* shrubs that grow in electromagnetic field areas might be different than other shrubs that grow in their natural environment.

The effect of EMF on organisms has become very important among scientists. The results of numerous researches deal with the sensitivity of organisms to the EMF effect. The effects may be useful and harmful depending on the intensity and frequency of the field, the period of exposure and the organism itself. Both effects seem to be very important to human life and activity.

Since the 1960's, different studies were conducted to identify the effects of electromagnetic field on living world. There were mixed opinions and results from these studies, positive, negative and no changes were reported ( Foster and Repacholi, 1999). The nature of the interaction of biological material with an electromagnetic source depends on the frequency of the source, so that different types of electromagnetic sources must be evaluated separately. Little research about the effect of high voltage transmission lines on physiological, morphological and metabolic parameters of plants exist in the literature, therefore, this chapter is outlining in brief the major and applicable previous research findings to represent the depth of scope of studies related to EMF effect on plant and soil properties.

**Effect of high voltage exposure on human health**

Humans are continuously exposed to electromagnetic fields (EMF) emitted from such sources as electric transmission lines, telecommunication and radio-television antennas. Thus resulting in EMFs of various frequencies is ubiquitous to our environment. The extensive network of high voltage (HV) transmission limits (TLs), electric engines in cars, trains and trams, welding devices, and the electrical appliances are the primary sources of extremely low frequency. All countries set their own national standards for exposure to EMFs.

However, the majority of these national standards draw on the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The effects of chronic exposure to environmental EMF have been the subject of intensive researches (Djanab, 1960), unfortunately, leading to no definitive answers. However, possible risks for childhood and adult leukemia have been acknowledged (Portier and Wolfe, 1998; Wartenberg, 1998 and Yang *et al*., 2008). Moreover, many other health outcomes are reported, among them are breast cancer (Stevens and Davis, 1996), neuropsychological disorders (Sobel*et al*., 1996; Verkasalo*et al*., 1997; and Liu *et al*., 2008), decrease in blood sugar (Abbasi and Nakhjavani, 2002), and reproductive outcomes (Hatch, 1992; Roychoudhury*et al*., 2009). Earlier, Reiter, (1993) reported that, the underlying mechanism that could explain all of these potential effects is alteration of melatonin secretion as a result of EMF exposure. Melatonin secretion is important in the regulation of circadian rhythms and sleep (Brzezinski, 1997), it could also be involved in the aging process (Poeggeler*et al*., 1993), carcinogenesis (Fedrowitz and Loscher, 2008), and reproduction (Reiter, 1998). In conclusion, that extremely low frequency magnetic fields are possibly carcinogenic is valid. This was concluded based on studies indicating that children exposed to relatively strong magnetic fields from power lines were more likely to develop leukemia (Draper *et al*., 2005). In European countries, the proportion of children exposed to such levels is less than 1% (Annonymous[a] 2007).

## II. CONCLUSION

- Electromagnetic field (EMF) generated around this network interferes with plant and human tissues but the mechanisms are not clear.
- The effects of magnetic fields on plants may be species-specific and/or is dependent on the characteristics of field exposure such as intensity and duration.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 1, Januray 2016**

- The nature of the interaction of biological material with an electromagnetic source depends on the frequency of the source, so that different types of electromagnetic sources must be evaluated separately.
- The finding that of EMF's effect on human health are possibly carcinogenic is valid. There are different results in the human health scope such as possible risks for childhood and adult leukemia, decrease in blood sugar, alteration of melatonin secretion, neuropsychological disorders, reproductive risk,…etc.
- Certain precautions can be taken to avoid EMF radiation such as accurate determining and avoiding the highest emitting levels, running an aquarium in the home to absorb microwave energy, limiting mobile phone use and using a wired internet connection that is safer than the wireless one.

.

## REFERENCES

1. Abbasi, M. and Nakhjavani, M."Biological effects of magnetic fields: Field effect on reducing blood sugar in mice", Iran. Mag. Diabetes and Lipid, Vol. 2(1), 59-63, 2002.
2. Ahmad, M.; Galland, P.; Ritz, T.; Wiltschko, R. and Wiltschko, W."Magnetic intensity affects cryptochrome dependent responses in Arabidopsis thaliana",Planta, Vol. 225(3), 615-624, 2007.
3. Alaish, F. M. Z. and Hassan S. M. Al-Zahrani, H. S. M."Biological activity of Calotropis procera grown under high voltage transmission lines in Jeddah province, Saudi Arabia",International Journal of Innovative Research in Science, Engineering and Technology. Vol. 3 (12), 18184-18192, 2014.
4. Annonymous[a],"About the extremely low frequency electromagnetic fields", Annual Report of World Health Organization (WHO), 2007.
5. Annonymous[b],"Annual Report of Saudi Electricity Company",Http://www.se.com.sa/NR/rdonlyres/2F4F7D91-34DC-4711-88F7826FBB9DF80/SE_EN_AnnualReport2013. pdf, 2013.
6. Annonymous[c], Saudi Electricity Company, WWW.SE.COM.SA. 2014.
7. Apasheva, L.M.; Lobanov, A.V. and Komissarov, G.C. "Effect of Alternating Electromagnetic Field on Early stages of Plant Development",DoklBiochem and Biophysics, Vol. 406, 1-3, 2006.
8. Atak, C.; Emiroglu, O.; Alikamanoglu, S. and Rzakoulieva, A. 2003. Stimulation of regeneration by magnetic field in soybean (Glycine max L. Merrill) tissue cultures, Cell MolBiol, Vol. 2, 113-119, 2003.
9. Atak, C.; Celik, O.; Olgun, A.; Alikamanolu, S. and Rzakoulieva, A.,"Effect of magnetic field on peroxidase activities of soybean tissue culture", Biotechnology, Vol. 21, 166-171, 2007.
10. Belyavskaya, N.A."Biological effects due to weak magnetic field on plants", Advances in Space Research, Vol. 34, 1566-1574, 2004.
11. Brzezinski, A.,"Melatonin in humans", N Engl J Med, Vol. 336 (3), 186-195, 1997.
12. Campbell, G.S.,"An Introduction to Environmental Biophysics", 2ed. Springer-Verlag, New York, USA, 1977.
13. Cherry, C.,"Evidence that electromagnetic fields from high voltage power lines and in buildings are hazardous to human health especially to young children", Department of human science, Lincoln University, New Zealand. Ed.: Bio Electric Shield, 2001.
14. Commoner, B.; Heise, J. and Townsend, J.,"Light-induced paramagnetism in chloroplasts",ProcNatlAcadSci USA, Vol. 42, 710-714, 1956.
15. Dardeniz, A.; Tayyar, V. and Yalçin, V.,"Influence of low frequency electro-magnetic field on the vegetative growth of grape CV Uslu", J. Central European Agriculture, Vol. 7(3), 389-396, 2006.
16. Davies, M.S.,"Effects of 60 Hz electromagnetic fields on early growth in three plant species and a replication of previous results",Bioelectromagnetics, Vol. 17(2), 154-161, 1996.
17. Demir, Z.,"Proximity effects of high voltage electric power transmission lines on ornamental plant growth", African Journal of Biotechnology, Vol. 9, 6486-6491, 2010.
18. Desrosiers, M.F. and Bandurski, R.S.,"Effect of a longitudinally applied voltage upon the growth of Zea mays seedlings", Journal of Plant Physiology, Vol. 87, 874-877, 1988.
19. Dhawi, F. and Al-Khayri, J.,"Proline accumulation in response to magnetic fields in date palm (*Phoenix dactylifera* L.)", Open Agri J, Vol. 2, 80-88, 2008.
20. Djanab, K.,"Report on some biological responses to high electric fields and indirect action of ultraviolet rays",ActaMedicaIranica, Vol. 3(2), 1-9, 1960.
21. Draper, G.; Vincent, T.; Kroll, M.E. and Swanson, J."Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study", BMJ, Vol. 330, 1290-1294, 2005.
22. Emlen, J.; Freeman, D. and Graham, J.,"Nonlinear growth dynamics and the origin of fluctuating asymmetry",Genetica, Vol. 89, 77-96, 1993.
23. Fedrowitz, M. and Löscher, W.,"Exposure of Fischer 344 rats to a weak power frequency magnetic field facilitates mammary tumorigenesis in the DMBA model of breast cancer", Carcinogenesis, Vol. 29, 186-193, 2008.
24. Flórez, M.; Carbonell, M.V. and Martínez, E.,"Early sprouting and first stages of growth of rice seeds exposed to a magnetic field". Electromagnetic Biology and Medicine, Vol. 23(2), 157-166, 2004.
25. Foster, K. and Repacholi, M., Environmental impacts of electromagnetic fields from major electrical technologies. International Seminar on Effects of electromagnetic fields on the living environment, Germany, 1999.
26. Freeman, C.D.; Graham, J.H.; Tracy, M.; Emlen, J.M. and Alados, C.L. 1999."Developmental instability as a means of assessing stress in plants: a case study using electromagnetic fields and soybeans". Int. J. Plant Sci, Vol. 160(6), 157-166, 1999.
27. Fromm, J. and Lautner, S.,"Electrical signals and their physiological significance in plants". Plant Cell Environment, Vol. 30, 249-257, 2007.
28. Goldsworthy A.,"The biological effects of weak electromagnetic fields". H.O.U.S.E. UK. goldsworthy bio. weak em 07.doc, 2007.
29. Graham, J.; Freeman, D. and Emlen, J.,"Antisymmetry, directional asymmetry and chaotic morphogenesis". Genetica, Vol. 89, 121-137, 1993.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, Januray 2016

30. Gurovich, L. A. and Hermosilla, P.," Electrical signaling in fruit trees in response to water applications and light-darkness conditions". Plant Physiology, Vol. 166, 290-300, 2009.
31. Hanafy, M.S.; Mohamed, H.A. and Abd El-Hady, E.A.," Effect of low frequency electric field on growth characteristics and protein molecular structure of the wheat plant". Rom. J. Biophys, Vol. 16(4), 253-271, 2006.
32. Hatch, M.," The Epidemiology of electric and magnetic field exposure in the power frequency range and reproductive outcomes". PaediatrPerinatEpidemiol, Vol. 6(2), 198-214, 1992.
33. Hindi. S. S. Z.," *Calotropis procera*: The miracle shrub in the Arabian Peninsula".International Journal of Science and Engineering Investigations (IJSEI).Vol. 2 (16),48-57, 2013.
34. Hindi, S. Z.," Characteristics of some natural fibrous assemblies for efficient oil spill cleanup". JKAU; Met. Env. Arid Land Agric. Sci. Vol. 25 (1), 149-165, 2014.
35. Hopkins, L.; Bond, M.A. and Tobin, A.K.," Ultraviolet-β radiation reduces the rates of cell division and elongation in primary leaf of wheat (*Triticumaestivum* L.)". Plant Cell Environment, Vol. 25, 617- 624, 2002.
36. Ivancsits, S.; Diem, E.; Jahn, O. and Rüdiger, H.W.," Intermittent extremely low frequency electromagnetic fields cause DNA damage in a dose dependent way". Int Arch Occup Environ Health, Vol. 76, 431-436, 2003.
37. Jansen, M.; Gaba, V. and Greenberg, B.M.," Higher plants and UV-β radiation: balancing damage, repair and accumulation". Trends Plants Sci, Vol. 3, 131-135, 1998.
38. Kostal, V.; Zahradnickova, H. and Simek, P.," Hyperprolinemia larvae of the arosophilid fly, Chymomyzacostata survive cryopreservation in liquid nitrogen". Paper presented at the The National Academy of Sciences of the United States of America, Vol. 108, 13041-13046, 2011.
39. Liang, Y.D.; Qi, G.Y.; Ming, Z.X.; Wen, W.S. and Pei, Q.," Effects of electromagnetic fields exposure on rapid micropropagation of beach plum (*Prunusmaritime*)". EcologEng, Vol. 35, 597- 601, 2009.
40. Liu, T.; Wang, S.; He, L. and Ye, K.," Anxiogenic effect of chronic exposure to extremely low frequency magnetic field in adult rats". NeurosciLett, Vol. 434(1), 12-17, 2008.
41. Martínez, E.; Carbonell, M.V. and Flórez, M.," Magnetic biostimulation of initial growth stag of wheat (*Triticumaestivum*, L.)". Electromagnetobiology and Medicine, Vol. 21(1), 43-53, 2004.
42. Moon, J.D. and Chung, H.S.," Acceleration of germination of tomato seed by applying AC electric and magnetic fields". Journal of Electrostatics, Vol. 48(2):103-114, 2000.
43. Nirmala, A. and Rao, P.N.," Genetic of chromosome numerical mosaicism in higher plants". Nucleus, Vol. 39, 151-175, 1996.
44. Noguse, S.; Allen, D.J. and Morison, J.," Ultraviolet-β effects on water relation, leaf development and photosynthesis in droughted pea plants". Plants Physiol, Vol. 117, 173- 181. 1998.
45. Paul, A.; Robert, F. and Meisel, M.," High magnetic field induced changes of gene expression in arabidopsis". BioMag Res Technol, Vol. 4: 7, 2006.
46. Pazur, A.; Rassadina, V.; Dandler, J. and Zoller, J.," Growth of etiolated barley plants in weak static and 50 Hz electromagnetic fields tuned to calcium ion cyclotron resonance". BioMagnetic Research and Technology, Vol. 4, 1, 2006.
47. Peňuelas, J.; Llusià, J.; Martínez, B. and Fontcuberta, J.," Diamagnetic Susceptibility and Root Growth Responses to Magnetic Fields in *Lens culinaris*, *Glycine soja* and *Triticumaestivum*". Electromagnetic Biology and Medicine, Vol. 23(2), 97-112, 2004.
48. Phirke, P.; Patil, N.; Umbarkar, S. and Dudhe, Y.," The application of magnetic treatment to seeds: methods and responses". Seed SciTechnol, Vol. 24, 365-373, 1996.
49. Plieth, C.," Temperature sensing by plants Calcium permeable channels as primary sensors, a model". J. Membrane Biology, Vol. 172, 121-127, 1999.
50. Poeggeler, B.; Reiter, R.J. and Tan, D.X." Melatonin Hydroxyl radical-mediated oxidative damage and Aging: A Hypothesis", J Pineal Re, Vol. 14: 151-168, 1993.
51. Portier, C.J. and Wolfe, M.S.," Assessment of health effects from exposure to power-line frequency electric and magnetic fields" (working group report), Research Triangle Park, NC: National Institute of Environmental Health Sciences of the National Institutes of Health, (NIH publication 98-3981), 1998.
52. Racuciu, M.; Creanga, D. and Amoraritei, C.," Biochemical changes induced by low frequency magnetic field exposure of vegetal organisms". Rom J Phys, Vol. 52, 601-606, 2007.
53. Racuciu, M.; Creanga, D. and Galugaru, C.," The influence of extremely low frequency magnetic field on tree seedlings". Rom J Phys, Vol. 35: 337-342, 2008.
54. Rakosy-Tican, L.; Aurori, C. and Morariu, V.," Influence of near null magnetic field on in vitro growth of potato and wild Solanum species". Bioelectromagnetics, Vol. 7, 548-557, 2005.
55. RamezaniVishki, F.; Majd, A.; NejadSattari, T. and Arbabian, P.S." Study of effects of extremely low frequency electromagnetic radiation on biochemical changes in *SaturejaBachtiarica* L.". International Journal of Scientific & Technology Research Vol. 1(7), 77-82, 2012[a].
56. RamezaniVishki, F.; Majd, A.; NejadSattari, T. and Arbabian, S.," Effects of electromagnetic field radiation on inducing physiological and biochemical changes in *Saturejabachtiarica* L.". Iranian Journal of Plant Physiology Vol. 2(4), 509-516, 2012[b].
57. Reiter, R.J." Electromagnetic fields and melatonin production". Biomed Pharmacother, Vol. 47, 439-444, 1993.
58. Reiter, R.J.," Melatonin and human reproduction". Ann Med, Vol. 30(1), 103-108, 1998.
59. Rochalska, M.," Influence of frequent magnetic field on chlorophyll content in leaves of sugar beet plants". Nukleonika, Vol. 50, 25-28, 2005.
60. Roychoudhury, S.; Jedlicka, J.; Parkanyi, V.; Rafa, J.; Ondruska, L.; Massanyi, P. and Bulla, J.," Influence of a 50 Hz extra low frequency electromagnetic field on spermatozoa motility and fertilization rates in rabbits", J Environ. Sci. and Health, Vol. 44, 1041-1047, 2009.
61. Shabrangi, A. and Majd, A.," Comparing effects of electromagnetic fields (60 Hz) on seed germination and seedling development in monocotyledon and dicotyledons". Progress in Electromagnet. Res. Symp. Proceed. Moscow, Russia, August 18-21, 2009.
62. Shawanroy," Electromagnetic Field" [power point slides] Retrieved from http://www.slideshare.net/shawanroy/electromagnetic-field-emf, 2012.
63. Siripornadulsil, S.; Traina, S.; Verma, D.P. and Sayre, R.T.," Molecular mechanisms of proline-mediated tolerance to toxic heavy metals in transgenic microalgae". Plant Cell, Vol. 14(11), 2837-2847, 2002.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, Januray 2016


64. Sobel, E.; Dunn, M. and Davanipour, Z.," Elevated risk of Alzheimer's disease among workers with likely electromagnetic field exposure". Neurology, Vol. 47, 1477-1481, 1996.
65. Somasekaran, S.," Effect of electromagnetic field on some selected crops". Reasearch, Vol. 147(3), 369-379, 2007.
66. Sood, V.," HVDC and Facts Controllers - Applications of static converters in power stages of wheat (*Triticumaestivum* L.)" . ElectromagBiol Med, Vol. 21, 43-53, 2004.
67. Stevens, R.G. and Davis, S.," The melatonin hypothesis: electric power and breast cancer". Environ Health, Vol. 104(1), 135–140, 1996.
68. Taia, W.; Al-Zahrani, H. and Kotbi, A.," The effect of static magnetic forces on water contents and photosynthetic pigments in sweet basil *Ocimumbasilicum* L.(Lamiaceae)" . Saudi J Bio Sci, Vol. 14, 103-107, 2007.
69. Tkalec, M., Malarić, K. and Kozlina, B. P.," Influence of 400, 900 and 1900 MHz electromagnetic fields on Lemna minor growth and peroxidase activity". Bioelectromagnetics, Vol. 26, 185-193, 2005.
70. Trebacz, K.; Dziubinska, H. and Krol, E.," Electrical signals in long distance communication in plants". Communication in Plants, Springer Berlin Heidelberg, 277–290, 2006.
71. Upadhyay, R.K. " Ethnomedicinal, pharmaceutical and pesticidal uses of *Calotropisprocera* (Aiton) (Family: Asclepiadaceae)" , IJGP, Vol. 8(3), 135-146, 2014.
72. Verbruggen, N. and C. Hermans.," Proline accumulation in plants: a review". Amino Acids, Vol. 35(4), 753–759, 2008.
73. Verkasalo, P.k.; Kaprio, J. and Varjonen, K.," Magnetic fields of transmission lines and depression". Am J Epidemiol, Vol. 146, 1037-1045, 1997.
74. Vorobiev, E. and Lebovka, N.," Electrotechnologies for extraction from food pants and biomaterials". Springer, 5996, 2008.
75. Walter, J. R.; Shitil, A.; Robinson, R.B. and Halian, D.," 60 Hz electric fields inhibit protein kinase C activity and multidrug resistance gene (MDRI) up - regulation". Rad Res Mar, Vol. 147 (3), 369 – 378, 1997.
76. Wartenberg, D.," Residential magnetic fields and childhood leukemia: a meta-analysis". Am JPublic Health, Vol. 88(12), 1787-1794, 1998.
77. Wuyts, N.; Dewaele, D. and Swennen. R.," Extraction and partial characterization of polyphenol oxidase from banana (Musa acuminate Grandrnaine) roots". Plant Physiology and Biochemistry, Vol. 44, 308-314, 2006.
78. Yang, Y.; Jin, X.; Yan, C.; Tian, Y.; Tang, J. and Shen, X.," Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia". Leuk Lymphoma, Vol. 49: 2344-2350, 2008.
79. Yano, A.; Ohashi, Y.; Hirasaki, T. and Fujiwara, K.," Effects of a 60 Hz magnetic field on photosynthetic $CO_2$ uptake and early growth of radish seedlings". Bioelectromagnetic, Vol. 25, 572-581, 2004.
80. Yao, Y.; Xuana, Z. and Li, Y. 2006. " Effect of Ultraviolet-β radiation on crop growth, development, yield and leaf pigment concentration of tartary buckwheat (*Fagopyrumtataricum*) under field conditions". Eur Journal Agon., Vol. 25, 215-222, 2006.