Comparing Effects of Electromagnetic Fields (60 Hz) on Seed Germination and Seedling Development in Monocotyledons and Dicotyledons

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Abstract— Various biological effects of exposure to extremely low frequency electromagnetic fields (ELF-EMFs) have been documented so far, but very little work has been carried out on plants. In this research, two states of seeds (wet, dry) of *Brassica napus L.* (dicot) and *Zea mays L* (monocot) were exposed to pulsed EMFs (15 min on, 15 min off) by magnitude of 1 to 7 mT in steps of 2 mT and the highest intensity was 10 mT for 1 to 4 hours in steps of 1 h. Exposure to EMFs was performed by a locally designed EMF generator. Three replicates, with 30 seeds in each one were placed in germinator with 23°C temperature after treatment. The number of germinated seeds was registered on the 2nd day after moisturizing in *Brassica napus* and 6th day after moisturizing in *Zea mays*. Developmental growth characteristics including: root and shoot length, fresh and dried biomass weight of 7 days seedlings were measured.

Seedlings grown from dry pretreated seeds of *Brassica napus* showed the most significant increase in developmental growth at 10 mT and seedlings grown from wet treated seeds showed the most significant decrease in developmental growth at 10 mT comparing to control ($p < 0.05$) we observed an overall stimulating effects of EMFs in *Zea mays* with respect to developmental growth characteristics and the most significant increase observed at 10 mT ($p < 0.05$). All experimental data suggested Monocotyledons are more resistant than Dicotyledons against EMFs as abiotic stress.

1. INTRODUCTION

The biological effects of extremely low frequency magnetic fields on living organisms have been explored in many studies. Most of them demonstrate the biological effects caused by 50/60 Hz magnetic fields or pulsed magnetic fields. Low frequency fields appears to be more bioactive (3). The basic mechanism is the forced-vibration of all the free ions on the surface of a cell plasma membrane, caused by an external oscillating field. Therefore vibration of electric charge is able to irregularly gate electro sensitive channels on the plasma membrane and thus cause disruption of the cells bioelectrical balance and function (14). The optimal external electromagnetic field could accelerate the activation of seed germination [5, 11]. But the mechanism of these actions is still poorly understood [8, 19]. It has been reported that external electromagnetic fields induce both the activation of ions and the polarization of dipoles in living cells [4, 16]. Electric and magnetic treatments are assumed to enhance seed vigor by inducing the biochemical processes that involve free radicals and by stimulating the activity of proteins and enzymes [10, 15, 20]. Field tests reported greater than 10% increase in the field of maize and wheat, after submitting the seeds to carefully controlled electric fields [13]. These effects were mainly attributed to the field — induced intensity cation of the biological processes in Seeds. The crop increase could also be related to the sterilizing effect of high-voltage application. Previous studies indicated that suitable magnetic treatment increased the absorption and assimilation of nutrients (6), and ameliorated photosynthetic activities (7). It has been also reported that MF increased seed germination, seedlings growth and biomass in lentil. Stress enzymes increased as well (16).

In this paper, the effects of AC electromagnetic fields on canola and maize seed germination have been carried out experimentally to investigate the potential of augmentation of seed germination and seedling developmental growth by the field intensity and exposure time. Authors aimed to compare effects of EMFs on monocotyledons and dicotyledons. Different growth characteristics of seeds treated of canola as a representative of dicotyledons and maize, a representative of monocot yledons were analyzed and compared with those of the untreated seeds.

2. MATERIAL AND METHODS

Exposure to EMFs was performed by a locally designed EMF generator. The electrical power was provided by a 220 V, AC power supply with variable voltages and currents. This system consisted of one coil, cylindrical in form, made of polyethelen with 12 cm in diameter and 50 cm in length. The number of turns is 1000 of 0.5 mm copper wire, which were in two layers. A fan was employed to avoid the increase of temperature ($22 + 1^{\circ}$C). Calibration of the system as well as tests for the accuracy and uniformity of EMFs (60 Hz) were performed by a tesla meter with a probe type of hall sound. Three replicates, with 30 seeds in each one were used. They were spread in moist filter paper (for wet seeds) on Petri dishes. They were placed in the coil. Analogous groups were used as control. The wet and dry seeds of two species were exposed to pulsed EMFs (15 min on, 15 min off) by magnitude of 1 to 7 mT in steps of 2 mT and the highest intensity was 10 mT for 1 to 4 hours in steps of 1 h. Then dry seeds in Petri dishes were moistened and all Petri dishes were placed in germinator with 23°C temperature. The number of germinated seeds was registered on the 2nd and 6th days after moisturizing in canola and maize. Five 7 days seedlings from each replicate were randomly taken for measuring shoot and root length in cm. Then fresh weights of them were measured. Subsequently, they were dried in an oven at 60°C for 24 hours and dried weight of them was measured too. The data was analyzed using the software SPSS12. The variance analyses ANOVA and DUNCAN's tests were used to calculate the level of differences of all measured traits among EMFs, duration of exposure and their interaction ($P < 0.05$).

3. STATISTICAL ANALYSIS

Statistical analysis of the data was performed by using ANOVA. We applied Duncan's multiple range test to compare the experimental results of groups exposed to an electromagnetic field for seed germination rate, seedling shoot and root length, fresh and dried biomass with control. For statistical evaluation of results, significance was defined by a probability level of $p < 0.05$.

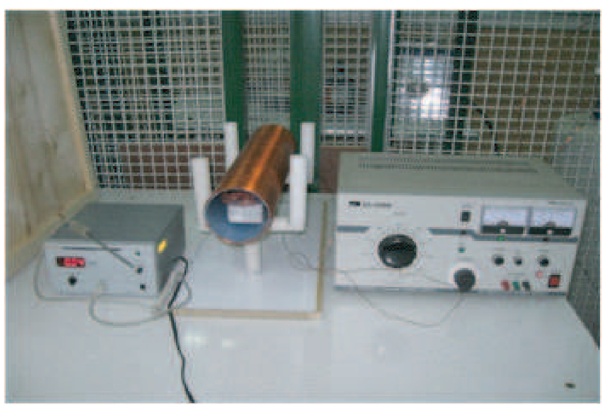

Figure 1: Set up of system.

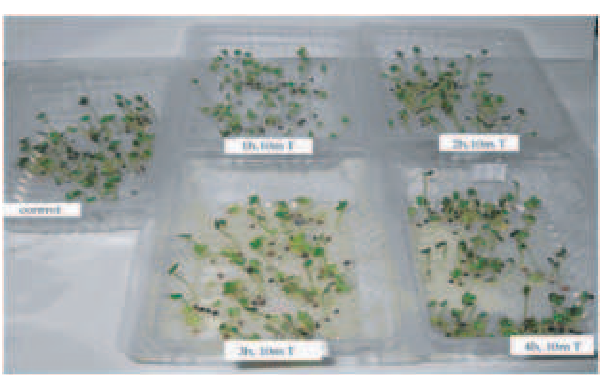

Figure 2: Dry pretreated seeds of canola by 10 mT. Intensity for different periods of time.

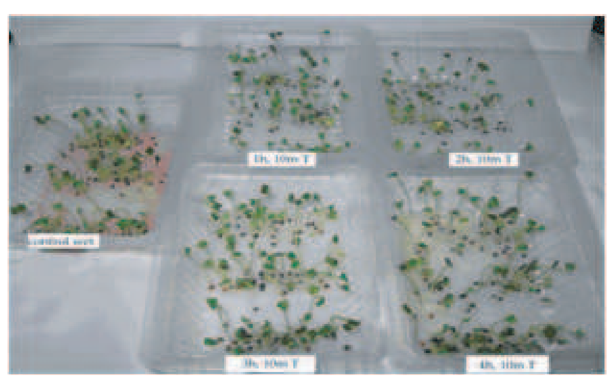

Figure 3: Wet treated seeds of canola by 10 mT. Intensity for different periods of time.

4. RESULTS

All experimental data and statistic calculations have attracted attention to interaction of EMFs and exposure time. Seed germination rate of wet treated seeds in maize and dry pretreated seeds in canola showed significant differences between all intensities of EMFs, duration of exposure and their interaction (Tables 1 and 2). Other developmental growth parameters including: root and shoot length of 7 days seedlings, fresh and dried biomass weights in canola showed just significant differences between intensities of EMFs. On the other hand in maize most of developmental growth parameters in seedlings grown from both wet and dry pretreated seeds showed significant differences between intensities of EMFs, duration of exposure and their interaction (Tables 1 and 2).

Table 1: Significant differences between intensities of EMF, duration of exposure and their interaction ($p < 0.05$)*.

time	seed germination	root & shoot length		fresh & dried biomass (±SD)	
	Dry pretreated seeds in canola (10 mT)				
0	*95.4 ± 5	3.2 ± 0.9	1.7 ± 0.35	0.057 ± 0.003	0.0037 ± 0.0005
1 h	*88.7 ± 8.1	4.2 ± 0.9	2.2 ± 0.1	0.071 ± 0.002	0.0037 ± 0.0003
2 h	*89.7 ± 8.5	3.7 ± 0.4	2.1 ± 0.5	0.062 ± 0.016	0.004 ± 0.0002
3 h	88.4 ± 4	5.1 ± 0.6	1.9 ± 0.35	0.056 ± 0.008	0.0037 ± 0.0004
4 h	*92 ± 3.54	1 ± 0.3	2.4 ± 0.35	0.057 ± 0.006	0.0038 ± 0.0002
	Dry treated seeds in maize (10 mT)				
0	70.7 ± 0	*2.2 ± 0.38	*1.4 ± 0.67	*0.54 ± 0.14	0.231 ± 0
1 h	79.7 ± 0	*1.6 ± 0.31	*0.9 ± 0.12	0.7 ± 0.1	0.249 ± 0
2 h	79.7 ± 0	*4.2 ± 0.76	*1.9 ± 0.46	*0.67 ± 0.1	0.273 ± 0
3 h	77.4 ± 0	*0.8 ± 1.13	*1.8 ± 0.25	*0.69 ± 0.11	0.261 ± 0
4 h	79.7 ± 0	*2.9 ± 0.78	*1. ± 0.28	*0.54 ± 0.14	0.266 ± 0

Table 2: Significant differences between intensities of EMF, duration of exposure and their interaction ($p < 0.05$)*.

time	seed germination	root & shoot length		fresh & dried biomass (±SD)	
	Wet treated seeds in canola (10 mT)				
0	96.7 ± 3.6	5.6 ± 0.6	3.2 ± 0.355	0.075 ± 0.002	0.0043 ± 0.0004
1 h	92 ± 3.6	5.4 ± 0.1	2.5 ± 0.215	0.036 ± 0.015	0.0029 ± 0.0008
2 h	88.7 ± 5.1	4.9 ± 1.6	2 ± 0.89	0.067 ± 0.015	0.0036 ± 0.0004
3 h	92 ± 5.1	5.6 ± 0.5	2.7 ± 0.365	0.064 ± 0.009	0.0035 ± 0.0001
4 h	94.4 ± 12	5 ± 0.8	2.8 ± 0.2	0.057 ± 0.013	0.0032 ± 0.0006
	Wet treated seeds in maize (10 mT)				
0	*48.7 ± 5.7	2.08 ± 0.38	*2.08 ± 0.14	*0.528 ± 0.09	0.257 ± 0.02
1 h	*45.4 ± 7.2	1.9 ± 0.173	*1.43 ± 0.23	*0.54 ± 0.08	0.282 ± 0.03
2 h	*44.4 ± 1.7	2.43 ± 0.55	*1.46 ± 0.4	*0.585 ± 0.13	0.272 ± 0.03
3 h	*56.4 ± 6.8	3.3 ± 0.776	*2.66 ± 0.14	*0.692 ± 0.06	0.269 ± 0.02
4 h	*69.7 ± 11.9	3.27 ± 0.901	*3.3 ± 1.35	*0.717 ± 0.1	0.279 ± 0.06

It indicates that certain combination of EMF and duration like 10 mT for 4 h (Figs. 4 and 5) in maize seedlings grown from wet treated seeds has highly effects on enhancing most of developmental growth. Furthermore, in canola EMFs intensities were highly effective in enhancing or avoiding growth parameters. There is a window at 10m T intensity for 2 hours time treatment in wet states seeds of canola, which negatively interacts and reduce the seedlings growth traits compared to control (Fig. 3). Beside, at the same intensity of EMF, seedlings grown from dry pretreated seeds were highly effective in enhancing growth parameters (Fig. 2). Therefore in canola two states of seeds treatment showed different results. However, we observed overall stimulating effects of EMFs in maize with respect to developmental growth characteristics.

Seed germination rate and developmental growth characteristics including: root and shoot length, fresh and dried biomass weight of 7 days seedlings, which were treated by 10 mT intensity of EMF for different periods of time, are shown in Figs. 6 to 10. Each figure shows comparing one of growth parameter in different states of seeds and species.

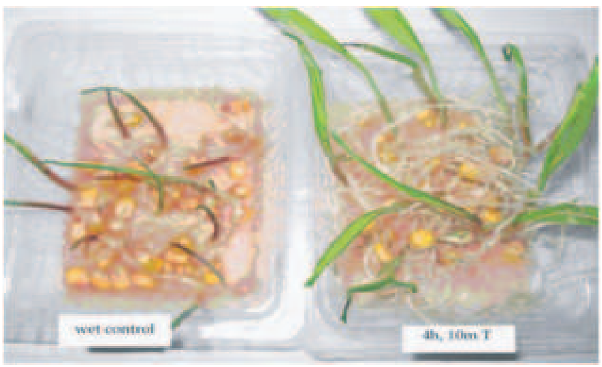

Figure 4: Wet treated seeds of maize by 10 mT. Intensity for 4 hours treatment.

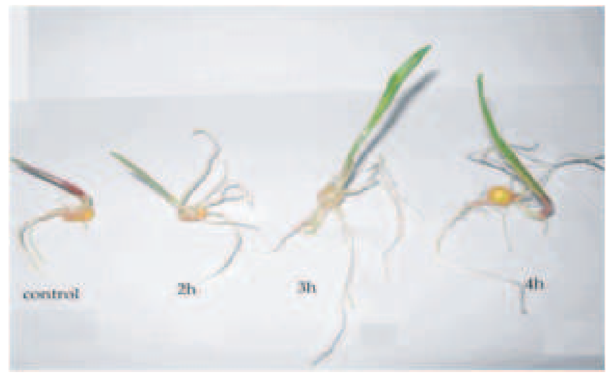

Figure 5: Wet treated seeds of maize by 10 mT. Intensity for different periods of time.

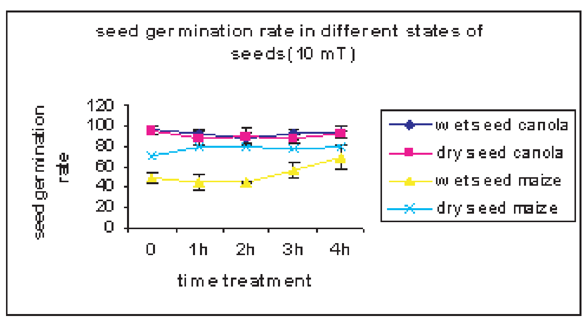

Figure 6: Comparing seed germination rate in different species and states of seeds treated by 10 mT for different time treatment.

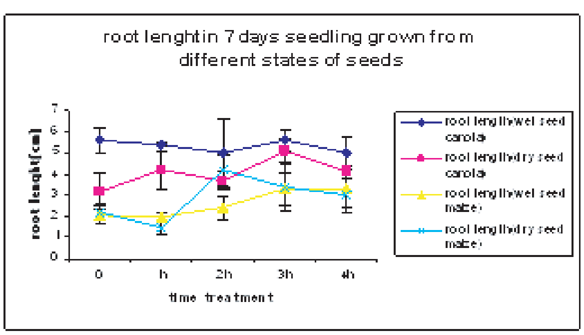

Figure 7: Comparing root length in different species and states of seeds treated by 10 mT for different time treatment.

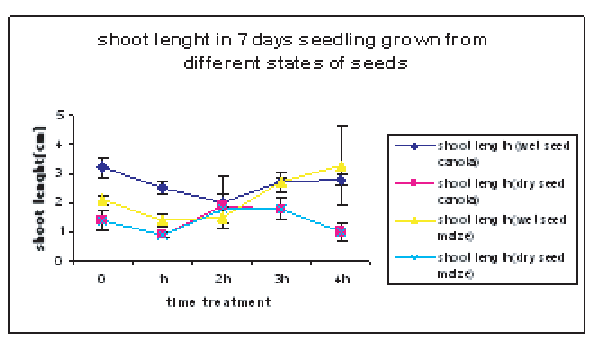

Figure 8: Comparing shoot length in different species and states of seeds treated by 10 mT for different time treatment.

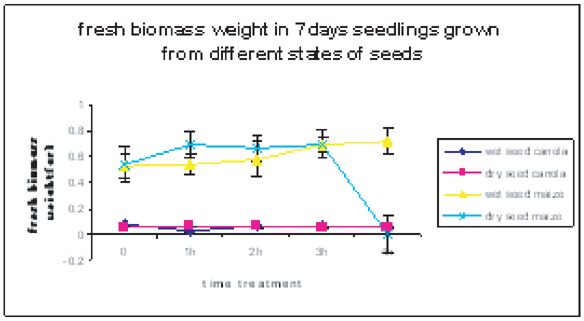

Figure 9: Comparing fresh biomass weight in different species and states of seeds treated by 10 mT for different time treatment.

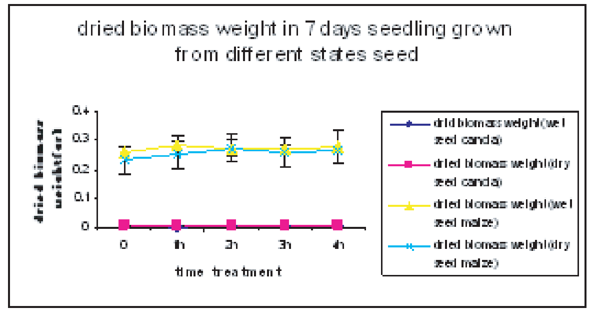

Figure 10: Comparing dry biomass weight in different species and states of seeds treated By 10 mT for different time treatment.

5. CONCLUSION

Monocotyledons are assumed to be more evolved than dicotyledons in phylogenic trends. As one of physical pre-sowing seed treatments that increased growth of cultivated plants, effects of electromagnetic flux density field treatment on biological systems, had been discussed for more than a century. Our results showed that electromagnetic fields treatment can affects seed germination rate and developmental growth characteristics, which was consistent with some previous studies (10) and (11). The authors found that suitable EMFs treatment (10 mT) could speed up seedling development and increase biomass. Similar result were also reported in cauliflower, tomato and cucumber (21). The effects of different intensities and exposure time of AC electric fields and AC magnetic fields on tomato seed germination have been investigated as a potential means to accelerate the germination of the seeds.

In this research, the rate of germination of different states treated seeds was higher than untreated seed in maize and we observed overall stimulating effects of EMFs in Maize with respect to developmental growth characteristics. In contrast, seedlings grown from two states of seeds under EMFs effects showed different results. We observed decreasing in seedlings growth and biomass of canola, which were grown from wet treated seeds, exposing to 10 mT intensity. Therefore, it would be deduced that Monocotyledon plants (maize) are more resistant than dicotyledons (canola). Authors believe these differences between two kinds of species depend on not only the genotype of species, but also hardness of seeds and stored polysaccharides in seeds which cover embryo.

The present study, in accordance with other studies demonstrates that pulsed fields can have increased biological action in relation to continues (uninterrupted) fields. Considering that these plants have ferritin cells containing 4500 Fe atoms, it is obvious that they have an outstanding role in the plants growth. As the last spin magnetic moment of the Fe atom posed to an external magnetic field, the composition of them creates an oscillator in the system. Then we have a moment of force on ferritin cells. This oscillator exerts its energy and locates in the field direction. The relaxed energy increased the internal temperature. This phenomenon occurs in the initial minutes of applying the magnetic field. So it depends on the number of times of locating the plant in magnetic field (19). On the other hand, a cell is considered to be an electrical system and electrical loading body. In fact, EMFs forced ions, molecules, macromolecules. Their interactions with biological constructions may cause changing in their energy level and also alteration in their construction. Therefore effects of potential energy of EMFs on cellular physiological functions need more research.

In conclusion, maize as a representative of monocotyledons is more resistant than canola (dicotyledons) against EMFS as a biotic stress.

REFERENCES

1. Bertholon, A., UG berElektrizitaK t in Berziehung auf die P#anzen, Leipzig, 1785.
2. Nelson, S. O. and E. R. Walker, *J. Agric. Eng.*, Vol. 42, 688, 1961.
3. Huang, H. H. and S. R. Wang, "The effects of inverter magnetic fields on early seed germination of mung beans," *Bioelectromagnetics*, Vol. 29, 649–657, 2008.
4. Johnson, C. C. and A. W. Guy, "Non ionizing electrostatic wave effects in biological materials and system," *Proc. IEEE*, Vol. 60, No. 6, 692–718, 1972.

5. Kavi, P. S., "The effect of non-homogeneous gradient magnetic field susceptibility values in situ ragi seed material," *Mysore J. Agric. Sci.*, Vol. 17, 121–123, 1983.
6. Lebedev, I. S. and L. T. Litvinenko, "After effect of a permanent magnetic field on photochemical activity of chloroplast," *Sovient Plant Physiol.*, Vol. 24, 394–395, 1977.
7. Maeda, H., "Do the living things feel the magnetics," *Kodansha*, Tokyo, 1993.
8. Morar, R., A. Iuga, and L. Dascalescu, "Separation and bio stimulation of Soybeans using high-intensity electric fields," *Proceedings of the International Conference on Modern Electrostatics*, 158–160, Beijing, China, 1988.
9. Murphy, J. D., "The influence of magnetic field on seed germination," *Am. J. Bot.*, Vol. 29, 15, 1942.
10. Murr, L. E., "Plant growth response in electrostaticfield," *Nature*, Vol. 207, 1177–1178, 1965.
11. Oomor, U. I., *Bioelectromagnetics and Its Applications*, Chap. 2.1.2, 340–346, Fuji Technosystem Ltd., 1992.
12. Panagopoulos, D. J., et al., "Mechanism for action of electromagnetic fields on cells," *Biochemical and Biophysical Research Communications*, Vol. 298, 2002.
13. Shabrangi, A. and A. Majd, "Effects of magnetic fields on growth and antioxidant system in plants," *Progress In Electromagnetics Research*, PIER 29, 1089–1094, 2009.
14. Sidaway, G. H. and G. F. Asprey, "Influence of electrostatic fields on seeds germination," *Nature*, Vol. 211, 303, 1966.
15. Takahashi, H., *Electricity and Life*, Institute Publication Center, Tokyo, 1986.
16. Townsend, J. S., "The diffusion and mobility of ions in a magnetic field," *Proc. Roy. Soc. A&B*, 571–577, 1912.
17. Vaezzadeh, M., et al., "Excitation of growth in dormant temperature by steady magnetic field," *Magnetism and Magnetic Material*, Vol. 302, 105–108, 2005.
18. Xiyao, B., M. Ancheng, M. Jingrun, and L. Xiaoling, "Physiological and biochemical experiments in electrostatic treated seeds," *Proceedings of the International Conference on Modern Electrostatics*, 161–165, Beijing, China, 1988.
19. Yinan, Y., et al., "Effect of seed pretreatment by magnetic field on the sensitivity of cucumber (Cucumis sativus) seedlings to ultraviolet-B radiation," 2004.
20. Ming, Y. J., "Effects of high-voltage electrostatic field on growth in plants," *Proceedings of the International Conference on Modern Electrostatics*, 161–165, Beijing, China, 1988.