This article is a 'work in progress' incorporating new information whenever time permits.

Fungi, plants, trees, seeds and EMFs

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Roux (2008) found that 900 MHz RF radiation below thermal levels affected plants. When exposed, the plants initiated "self-repair" processes very similar to those expected when the plant perceives itself to be injured. Roux concluded *"Taken as a whole, the data provide new evidence supporting the hypothesis that plants perceive and respond to microwave irradiation as though it was an injurious treatment."*

Tkalec (2009) found cellular effects in germinating onions when they were exposed to 400 and 900 MHz electric fields of 41 and 120 V/m. Whilst the upper value is above ICNIRP the lower value is not, and a quite feasible field level to be received by the head when talking on a mobile phone.

Sharma (2009) concluded that mobile phone radiation inhibited root growth of mung beans by inducing ROS-generated oxidative stress despite increased activities of antioxidant enzymes. Another study by Singh (2012) confirmed that mobile phone radiation affected biochemical processes manifesting as oxidative stress which impaired root growth in mung beans.

Fungi

Electromagnetic fields were found to promote hyphal growth in Tuber borchii (Potenza 2012).

Plants

Gagliano (2012) found that seeds and seedlings of the chili plant, Capsicum annuum, are able to sense neighbours and identify relatives using alternative mechanisms beyond previously studied channels of plant communication. The authors offer a hypothetical mechanistic explanation as to how plants may do this by quantum-assisted magnetic and/or acoustic sensing and signaling.

Pulsed electromagnetic fields as a presowing treatment was found to enhance plant growth in tomato plants. Yield per plant was higher in magnetic field treatments (Efthimiadou 2014).

Pulsed electric field processing could be a suitable process to stimulate production of broccoli with high health-promoting glucosinolate content (Aguiló-Aguayo 2014).

Isaac Alemán (2014) suggested that the application of 60 Hz magnetic field to in vitro coffee plants may improve the seedlings quality by modifying some photosynthetic physiological and molecular processes, increasing their vigour, and ensuring better plant development in later stages.

Exposure to sustained low intensity microwaves can constitute a stress for the Ocimum basilicum (basil) plants, reducing the emissions of volatile organic compounds. Microwave irradiation reduces those qualities of oils that make this plant a very sought-after flavour, including as pesto, in kitchens (Lung 2016).

Wheat grain yields were 7% higher (average of 5 years) in the plots with the lowest field exposure than in the plots nearer to a high voltage transmission line (Soja 2003).

Halgamuge (2015) found that observed effects on the growth of soybean seedlings were significantly dependent on field strength as well as amplitude modulation of the applied field.

Seeds

Pretreatment of PMF plays important roles in improvement of crop productivity of soybean through the enhancement of protein, mineral accumulation and enzyme activities which lead to increases in growth and yield (Radhakrishnan & Ranjitha Kumari 2012, Asghar 2016, Asghar 2017). A further study by the same team found that 10 Hz PMF treatment enhanced the germination and seedling growth of soybeans (Radhakrishnan & B Kumari 2013).

Results indicate that static magnetic field application enhanced maize seed performance in terms of percentage germination, speed of germination, seedling length, and seedling dry weight significantly compared to unexposed control. Plants raised from seeds exposed to 200 mT for 1 h had higher values of leaf area index, shoot length, number of leaves, chlorophyll content, shoot/root dry weight, and root characteristics as compared to corresponding values in untreated control (Vashisth 2017).

Microwave pretreatment for 5 or 10 seconds conferred tolerance to cadmium stress in wheat seedlings (Qiu 2011). The results also showed that the microwave radiation had a positive physiological effect on the growth and development of cadmium stressed seedlings. Pre-seed electromagnetic treatment has been used to minimise drought-induced adverse effects on maize (Javed 2011).

Pulsed electromagnetic fields have been found to promote germination and improve early growth characteristics of cotton seedlings. Such priming techniques are especially valuable in organic cultivation, where chemical compounds are prohibited. Magnetic field treatment of 15 minutes was found to stimulate germination percentage and to promote seeds, resulting in 85% higher values than control seeds under real field conditions. Seeds that were treated with a magnetic field performed better in terms of early-stage measurements and root characteristics (Bilalis 2012).

In soil, seeds exposed to static magnetic fields produced significantly increased seedling dry weights, dramatic increase in root length, root surface area and root volume. The improved

functional root parameters suggest that magnetically treated chickpea seeds may perform better under rainfed (un-irrigated) conditions where there is a restrictive soil moisture regime (Vashisth & Nagarajan 2008).

Seeds pre-primed for 6 minutes on and off pulsed magnetic fields showed significant improvement in germination (7.6%) and vigor (84.8%) over unexposed aged seeds (Bhardwaj 2016).

Germination enhancement was optimum for the mung beans exposed to 100 mW for 1 hour power-duration level, while for water convolvuluses the optimum germination power-duration level was 1 mW for 2 hours. When both seed types were exposed at the early sprouting phase with their respective optimum power-duration levels for optimum seed growth, water convolvuluses showed growth enhancement while mung bean sprouts showed no effects (Jinapang 2010). Perhaps discrepancies may be explained by the results of one experiment where the growth in mung beans exposed to low frequency EMF was inhibited at low field intensity, but was enhanced at a higher intensity (Costanzo 2011). There may be other considerations with respect to differential research findings. The results of a study by Huang & Wang (2008) indicate that the magnetic field induced by a 20 or 60 Hz SPWM voltage (sinusoidal oulsed width modulation) has an enhancing effect on the early growth of mung beans, but the magnetic fields induced by SPWM voltages of other frequencies (30, 40, and 50 Hz) have an inhibitory effect, especially at 50 Hz.

Fermentations of the yeast S cerevisiae with magnetic treatment reached their final stage in less time, i.e., approximately 2 hours earlier than controls (Perez 2007).

Treatment of sunflower seeds in magnetic fields increased the speed of germination, seedling length and seedling dry weight under laboratory germination tests (Vashisth & Nagarajan 2010). Exposure of seeds to magnetic fields improved seed coat membrane integrity and reduced the cellular leakage and electrical conductivity. Treated seeds planted in soil resulted in statistically higher seedling dry weight, root length, root surface area and root volume in 1-month-old seedlings. Higher enzyme activity in magnetic-field-treated sunflower seeds could be triggering the fast germination and early vigour of seedlings.

Poinapen (2013) found higher germination (~11.0%) was observed in magnetically-exposed seeds than in non-exposed ones, although seedlings emerging from static magnetic field treatments did not show a consistent increase in biomass accumulation.

Results from a study by Aydin (2016) suggested that low intensity static magnetic field may trigger genomic instability and DNA methylation in wheat.

Trees

Fresh and dry weight of leaves, content of MDA, proline, and protein increased in both healthy and infected plants under electromagnetic fields, compared with those of the control plants. EMFs decreased hydrogen peroxide and carbohydrates content in both healthy and infected 2-year old Lime trees compared to those of the controls (Abdollahi 2012).

In a study by Waldmann-Selsam (2016) that looked at trees near mobile phone base stations, the measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. The damage inflicted on trees by mobile phone towers usually start on one side, extending to the whole tree over time.

Water

Electromagnetic-treated water was found to have diverse biological effects on both animal and plant cells (Yamabhai 2014).

Amyan & Ayrapetyan (2004) suggested that EMF-treated water has a different biological effect on the process of barley seed hydration, solubility and water binding in seed and germination. Frequency "windows" for the effect of EMF were discovered, which could explain variability in studies.

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