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Effect of man-made electromagnetic fields on common B*rassicaceae Lepidium sativum* (cress d'Alinois) seed germination: a preliminary replication study

Efecto de campos magnéticos artificiales en la germinación de *Lepidium sativum* (Brassicaceae): un estudio preliminar

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Abstract. Under high levels of radiation (70-100 μW/m2 =175 mV/m), seeds of Brassicaceae *Lepidium sativum* (cress d'Alinois) never germinated. In fact, the first step of seeds' germination – e.g. imbibitions of germinal cells – could not occur under radiation, while inside the humid compost such imbibitions occurred and roots slightly developed. When removed from the electromagnetic field, seeds germinated normally. The radiation was, thus, most likely the cause of the non-occurrence of the seeds' imbibitions and germination.

Keywords: Imbibitions; Seeds; Water; Wireless waves.

Resumen. Las semillas de *Lepidium sativum*, Brassicaceae, nunca germinaron bajo altos niveles de radiación (70-100 μW/m2 =175 mV/m). En realidad, el primer paso en la germinación de las semillas - ej. imbibición de las células germinales - no ocurrió bajo radiación, mientras que tal imbibición ocurrió dentro del compost húmedo y las raíces desarrollaron un poco. Cuando las semillas fueron removidas del campo magnético, las mismas desarrollaron normalmente. La radiación fue obviamente la causa que no ocurriera la imbibición y la germinación de las semillas.

Palabras clave: Inhibición; Semillas; Agua; Ondas inalámbricas.

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INTRODUCTION

The present work was undertaken consequently to that performed by a group of Danish girls (Lea Nielson, Mathilde Nielsen, Signe Nielsen, Sisse Coltau and Rikke Holm), at Hjallerup Skole, under the supervision of their biology teacher Mr. Kim Horsevad. These girls made an experiment as a part of a national science fair/competition for high school pupils about which more information can be found at the website www.ungeforskere.dk

All started when the girls had difficulties concentrating in their lessons. "We all thought we experienced concentration problems in school if we slept with our mobile phones at the bedside, and sometimes we also found we had difficulties sleeping". The five girls took 400 cress seeds and randomly spread them into 12 trays. They then placed the trays in two different rooms, at the same temperature, six in each room. They gave to the trays the same amount of water and sunlight over 12 days, but exposed six of the trays to mobile phone radiation. In other words, six trays of seeds were placed in a room with no radiation, while six were placed in another room alongside two activated routers emitted roughly the same type of radiation as a common mobile phone. The results were obvious: the cress seeds alongside the routers did not grow at all, and some even seemingly mutated or died.

The students repeated their experiment twice. The results in both were equally dramatic, and showed a dose-response effect between the two batches. The statistical significance of the biomass reduction in the students' tests with a p-value (2-tail) of <0.000005 is thought-provoking!

Great effort was made to characterize and measure the premises' background electromagnetic fields and the climatic conditions. No obvious confounders were then found that could give rise to - and explain - the different growth of the irradiated and the non-irradiated seeds.

It would be tempting to just discard such observations since they have not been performed under controlled conditions, thus not following all the rules of sciences. But often, observations done outside of the regular laboratory environments are the start of new discoveries. So, we decided to try to replicate the girls' work.

Man-made electromagnetic waves have actually largely been shown to have adverse effects on living organisms. They affect, for instance, mammals (Adang et al., 2006; Benlaidi & Kharroussi, 2011), birds (Everaert & Bauwens, 2007), amphibians (Balmori, 2006), bees (Kimmel et al., 2007, Sharma & Kumar, 2010; Favre, 2011), ants (Cammaerts et al., 2012, 2013), fruit flies (Panagopoulos et al., 2004; Panagopoulos, 2012), and even protozoa (Cammaerts et al., 2011). In fact, they act firstly and essentially on the cellular membrane and so affect any living organism (Cammaerts et al., 2011). Such waves have also been shown to impact plants (Roux et al., 2008; Haggerty, 2010), at physiological and ecological levels.

In order to bring some new information on the subject, we here examine if man-made electromagnetic waves impact plants' germination and more precisely the first events occurring at the beginning of that germination. We are conscious that our observations are only preliminary ones and that further studies (replication, cytological observations, and physiological studies) are necessary to verify the present finding and to understand what is actually and exactly occurring in germinal cells under radiation.

MATERIALS AND METHODS

Four identical series of seeds of Brassicaceae *Lepidium sativum* (cress d'Alinois) (same quantity, quality, origin, age) were deposited on identical compost (same initial sample), each one in an identical tray (20 cm x 15 cm x 4 cm). Compost is the commonly used material for obtaining germination of seeds. The compost was humidified with same quantity (100 ml) of the very same tap water. Two of these trays were set at a place where the electromagnetic field reached an intensity of 70 - 100 $\mu W/m^2$ (= about 175 mV/m), this being mainly due to the presence of two communication masts at about 200 meters of distance (Fig. 1). The two other trays were set at another place where the electromagnetic field had an intensity of about 2 - 3 $\mu W/m^2$ (= 30 mV/m). These two series of seeds, set under low radiation level, were used as the control sample. Since the existing electromagnetic fields were generated by communication masts, the frequencies of the emitted waves were 900 MHz and/or 1,800 MHz. The intensity of the electromagnetic fields was measured using an HF 35 C radiation intensity meter for frequencies from 800 MHz to 23 GHz (Gigahertz solutions GmbH, Am Galgenberg 12, D-90579 Langenzenn, Germany). All the other environmental conditions were near-identical for each of the two double series of seeds (temperature = 20 °C, humidity = 70%, luminosity ≈ 300 lux). The seeds were then observed after four, seven and ten days, and tap water was poured on the compost, equally for each series of seeds, at regular intervals. When obvious differences were surprisingly observed between the seeds set under the two different levels of electromagnetism exposition, samples of seeds were removed, attentively observed and examined under a stereomicroscope. Seeds which had been maintained under two different levels of radiation were drawn using a camera lucida (magnification = 25x), and *via* these drawings, their length and their width (two orthogonal segments) were measured in mm. The means of the obtained values were established and the distributions of values (for the length on one hand, for the width on the other hand) corresponding to each two kinds of seeds were statistically compared using the non-parametric χ^2 tests, the level of probability being set at p<0.05 (Siegel & Castellan, 1989). After these assessments, samples of each kind of seeds were set under the lower exposure and observed once more after two days.

Fig. 1. The two communication masts causing most of the electromagnetic field of 70 – 100 µW/m² in one of the experimental rooms.
Fig. 1. Los dos mástiles de comunicación causantes de la mayoría del campo electromagnético de 70 – 100 µW/m² en una de las salas experimentales.

Germination did not occur under 70 - 100 µW/m². After four days, the seeds set under the two different electromagnetic field strengths already differed: those under the lower level had begun to germinate while those under the higher level of electromagnetic field had not at all done so. After seven days in total, many seeds maintained under low level of exposure had completed their germination and other ones were in the process of their germination while the seeds set under the higher level of exposure appeared unchanged (when looking at them from above) (Fig. 2 A). The experiment was continued until a total of 10 days with, at that time, the same results as above: normal germination for the seeds under low radiation, apparently no germination for those set under the higher radiation.

In the humid compost, roots development occurred. Ten days after the beginning of the experiment, seeds set under the higher exposure (having not germinated) as well as seeds maintained under low exposure (being in the process of their germination) were collected, i.e. taken using small pins and put into cups. First, they were visually examined, and after that, observed under the stereomicroscope.

First, while doing this manipulation, we clearly detected some external difference between the two kinds of seeds. Those kept under higher radiation were dry, not clinging at all while those kept without nearly no radiation were wet, clinging, and often attached to one another.

Secondly, very surprisingly, inside the humid compost, small roots of seeds set under radiation had developed, nearly like for seeds kept without radiation, with the difference that, in the latter case, the roots were somewhat more developed (Fig. 2B). It might be possible that, inside the compost and the water it contains, the electromagnetic field either had a lower intensity (through shielding effects) or had its adverse effects decreased or even countered (compared to the situation existing above the compost). Of course, if the effects we see are dependent only on the radiation, the most sensitive plant parts would be the ones above the soil, and they would be the first to be affected/retracted/not developed.

Seeds' imbibitions did not occur under 70 - 100 µW/m². The two kinds of seed, collected as related above, were observed under a stereomicroscope, drawn (Fig. 2 C), and measured as explained in the 'Material and methods' section. For seeds set under 2 - 3 µW/m², the two variables on average equaled 0.51 mm and 0.27 mm while for seeds set under 70 - 100 µW/m², these variables on average equaled 0.45 mm and 0.21 mm. Statistically, 0.45 mm turned out only slightly different from 0.51 mm (χ^2 = 3.34; df = 1; p ≈ 0.05) while 0.21 mm strongly differed from 0.27 mm (χ^2 = 10.77; df = 1; p ≈ 0.001). The more affected variable was thus the seeds' width. Consequently, it could be presumed that without radiation, seeds normally went through the expected imbibitions phenomenon (the first step of the plants' germination) while under radiation, seeds were no longer able to go through this essential first step of their germination.

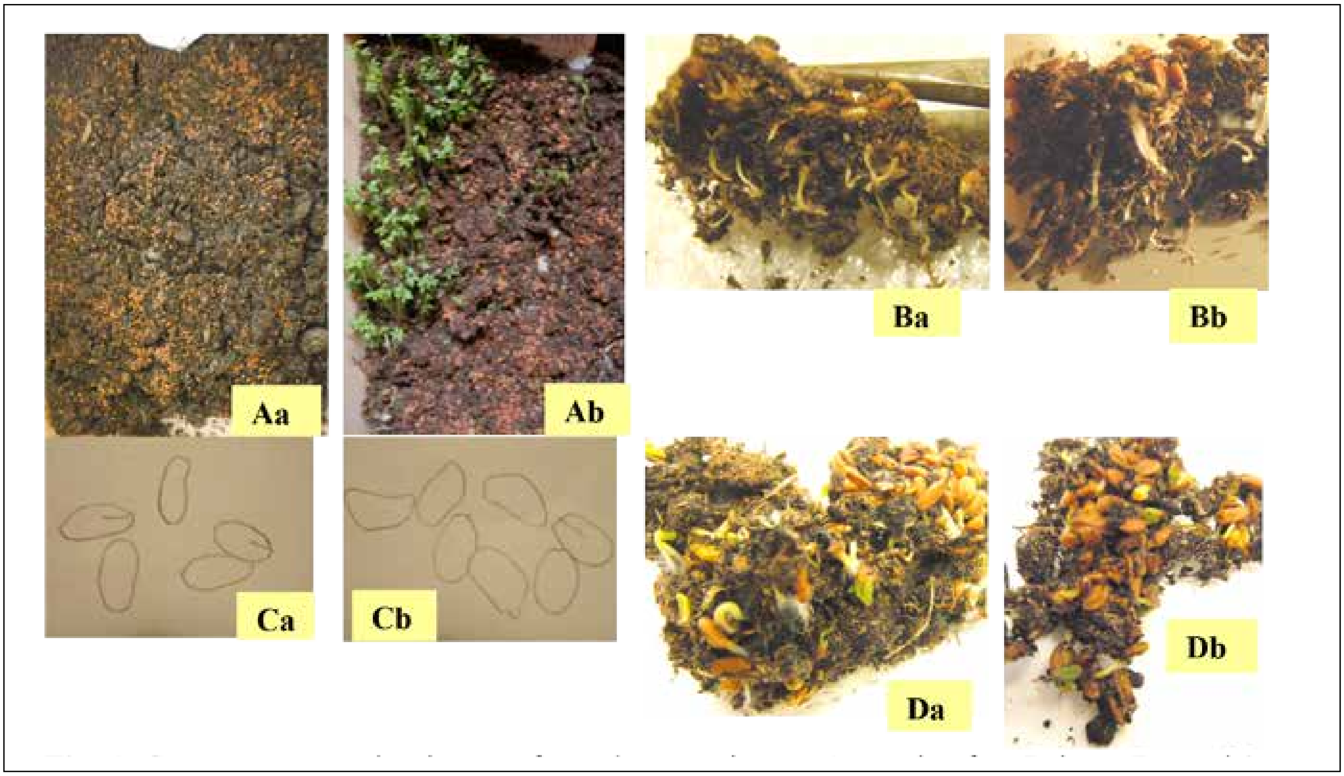

Fig. 2. Some representative images from the experiment. A: seeds after 7 days; B: seeds' roots after 10 days; C: drawings of seeds after 10 days; D: seeds removed from their initial location and set under 2 μW/m^2. Each time, for each image: a = seeds kept under 70 – 100 μW/m^2, and b: seeds kept under 2 – 3 μW/m^2.

Fig. 2. Algunas imágenes representativas del experimento. A: semillas luego de 7 días. B: raíces de semillas luego de 10 días. C: dibujos de las semillas luego de 10 días. D: Semillas removidas de su ubicación inicial y colocadas a 2μW/m^2. Cada vez, por cada imagen: a = semillas mantenidas a 70 – 100 μW/m^2, y b: semillas mantenidas a 2 – 3 μW/m^2.

According to the previous observation (see previous paragraph), it may be added that the germinal cells of the roots, located inside (surrounded by) humid compost, could realize such imbibitions.

Seeds exposed were still alive. The two kinds of collected seeds were then taken out of their initial location and set, each one, in a small tray (10 cm x 5 cm x 4 cm), the two trays then being deposited side by side, in a room where the level of radiation was low (2 μW/m^2). The seeds having begun their germination went on doing so and those having not germinated began to do so, this becoming apparent after two days (Fig. 2 D).

DISCUSSION

The fact that man-made electromagnetic waves probably have adverse effects on living organisms is actually more and more realized and admitted. Reviews on the subject exist (Pakhomov & Murphy, 2000; Fragopoulou et al., 2010; Sivani & Sudarsanam, 2012; Cucurachi et al., 2013). However, first, the mechanism underlying such adverse effects are not yet fully understood so it is difficult to counteract these effects while still going on using any wireless technology. Secondly, the revealed adverse effects apparently do not worry public health authorities, parliaments, governments, and - thus - not the general public who is not fully informed. Indeed, the wireless technology is actually more and more used, both for human work tasks and hobbies. Users are not worried probably because the revealed adverse effects appear not to be emergent for human beings, i.e. effects on Protozoan's locomotion (Cammaerts et al., 2011), on Drosophila's reproduction (Panagopoulos, 2012, Panagopoulos et al., 2004), on ants' memory (Cammaerts et al., 2012) and response to pheromones (Cammaerts et al., 2013), on bees' collection of pollen (Sharma & Kumar, 2010), on amphibian's embryogenesis (Balmori, 2006), on rat's memory (Adang et al., 2006), and so on, although they -of course- are! Here, we reveal yet an impact of man-made electromagnetic waves on a very important phenomenon: the germination of the seeds of plants. We show that the first essential step of the germination (= the imbibitions) seemingly does not occur under radiation and that the electromagnetic waves are the only likely cause of such a non-occurrence. We presume that the cellular membrane organization, the water and ions transfer through that membrane are perturbed. Indeed, we have previously shown that the cellular membrane is strongly affected by electromagnetism (Cammaerts et al., 2011), which explains, in our mind, the impact of such electromagnetism on nervous cells, reproduction and behavior. Other data are also in favor of such an assumption (see the review of Marino and Carrubba, 2009). Let us add that seeds are often deposited onto the ground and not set inside the earth, and are so potentially maximally exposed to electromagnetism. On the other hand, such electromagnetism has been shown to impact, among others, the health of plants (Belyavskaya, 2004; Roux et al., 2008; Haggerty, 2010; and four Web sites in the list of references). Plants are truly and very necessary for life on earth; people should now be very conscious of this potentially emerging problem!

In conclusion, the present investigation -although preliminary in its character- indicates that the prodigious wireless technology may effectively and seriously impact nature and should urgently be used much more cautiously (see also the published work of Doyon (2008)). The present study also brings some new information on the subject -effect of electromagnetism on plants- but it must be replicated on several plants species, at different independent laboratories, as well as developed further at the cytological and physiological levels by botanists, histologists and physiologists. Finally, in essence, it clearly supports the initial findings of Lea Nielson, Mathilde Nielsen, Signe Nielsen, Sisse Coltau and Rikke Holm, at Hjallerup Skole, under the supervision of their biology teacher Mr. Kim Horsevad.

Conflict of Interest Statement

The authors know of no conflict of interest related to this work.

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