Effects of Earth's magnetic field on plant growth, development and evolution

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The Earth's magnetic field or the geomagnetic field (GMF) is an environmental factor characterized by local differences in its magnitude and direction at the Earth's surface as well as polarity changes during the so called GMF reversals. Due to its transient instability, GMF is known to influence many biological processes of organisms living on our planet, including plants [1]. Recently, a correlation has been found between the occurrence of GMF reversals and the speciation of Angiosperms, implying a role of GMF in plant evolution [2]. However, the influence of MF of different intensities on plants shows conflicting experimental results and that of a MF lower than GMF has been rarely studied [1]. In particular, the condition of MF absence (Near Null Magnetic Field, NNMF) is becoming of wide interest, since interplanetary navigation will introduce not only plants, but also humans and animals to environments where the natural MF is almost zero. This condition is even the most suitable to investigate in detail the still unclear MF perception mechanism. Up to now, cryptochrome, a blue light photoreceptor, has been suggested as the possible *Arabidopsis* magnetoreceptor, since apparently involved in MF perception in avians [3].

Starting from this background, the general objectives of my PhD were: i) to substantiate the correlation between GMF reversals and plant evolution, testing the response of plants to both normal and reversed magnetic field; ii) to investigate the supposed role of photoreceptors in magnetoreception, evaluating NNMF influence on plant growth processes directly dependent from light perception (such as flowering and photomorphogenesis) using even photoreceptor mutants, iii) to estimate NNMF-induced changes on photoreceptor activation level. As a robust method to generate a stable reverse or reduce MF over a sufficient volume to grow plants, we used a Helmholtz coil system that is not commercially available due to the innovative octagonal shape of its coils. Each couple of coils is connected to a power supply manually controlled by a computer to compensate the GMF or to reverse any of the three GMF dimensions. MF values are monitored by a three-axis magnetometer in real time. All our experiments were performed both *in vitro* and *in vivo* on the model plant *Arabidopsis thaliana*, useful to be used for its fast life cycle, its small dimensions and its fully sequenced genome. Morphological, biomolecular (microarray, RNA-seq, qPCR) and proteomic (Western Blot) approaches were used to reach our objectives.

Our data show for the first time that reversing the GMF polarity has significant effects on *in vitro* early plant growth, thus confirming is probable affection on plant evolution. Root length and leaf area were both reduced under the reversed MF, in accordance with the altered expression of genes correlated to plant growth and oxidative response [4]. *In vivo* studies showed that even NNMF was able to affect plant morphology, reducing the leaf area index and the stem length during the plant reproductive growth stages and delaying the flowering time. Differently, we could not see any changes in the photomorphogenic morphology of plant early growth stages. However, NNMF affected not only the expression of genes specific of the early stages of flower induction, but also the expression of some genes correlated to the photomorphogenic response. The transcriptomic profile is even modified in *cry1cry2* mutant by NNMF, thus implying that NNMF also interfers with the expression of gene pathways directly downstream of the activation of photoreceptors others than cryptochrome. Our proteomic analyses confirmed a NNMF negative effect on cryptochrome activation under blue light as well as a repression of phytochrome B degradation under red light in a cryptochrome-dependent manner. Last but not least, the presence of a possible light-independent mechanism of magnetoreception in the roots together with changes in the activation of genes related to biotic and biotic stress response in flowering plants suggested an influence of MF on the global plant trascriptome, confirming the presence of a magnetoreceptor.

The obtained results highlight the effective influence of MF on plant growth, thus opening new frontiers of research towards other biological processes and organisms, such as animal models and human cancer cell lines. Changes in GMF polarity and intensity acquire an important value at the evolution level, opening new questions about the evolution of living organisms others than plants. Lastly, the exploration of plant responses to NNMF is a key point for the requirements of plant health status in space missions.

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