American Journal of
Biomedical Science & Research

www.biomedgrid.com
ISSN: 2642-1747

Minireview

Magnetic Fields in Plant Development: Unravelling the Complex Interplay from Phenotypic Responses to Molecular Dynamics

Gregory C Bernard[1*], Andrea Lockett[1], Sharan Asundi[2], Ivi L Mitchell[1], Marceline Egnin[1], Inocent Ritte[1], Osa Idehen[1] and Pamelas M Okoma[1]

[1] *College of Agriculture, Environment, and Nutrition Sciences, Tuskegee University, Tuskegee*

[2] *Mechanical & Aerospace Engineering, Old Dominion University, Norfolk, VA*

***Corresponding author:** Gregory C Bernard, College of Agriculture, Environment, and Nutrition Sciences, Tuskegee University, Tuskegee, AL, 36088.

To Cite This Article: *Gregory C Bernard*, Andrea Lockett, Sharan Asundi, Ivi L Mitchell, Marceline Egnin, Inocent Ritte, Osa Idehen and Pamelas M Okoma, Magnetic Fields in Plant Development: Unravelling the Complex Interplay from Phenotypic Responses to Molecular Dynamics. Am J Biomed Sci & Res. 2024 21(4) AJBSR.MS.ID.002854,* DOI: 10.34297/AJBSR.2024.21.002854

Received: : February 06, 2024; **Published:** February 09, 2024

Abstract

The geomagnetic field (GMF) is a pervasive environmental factor shaping the development of living organisms, particularly plants. This mini review traces the historical evolution of magnetic field research in plants, highlighting early experiments by Krylov, Tarakonova, and others and the subsequent development of controlled experimental setups using shielding and Helmholtz coils. Phenotypic responses to magnetic fields, ranging from growth and productivity enhancements in various crops to impacts on overall plant health, protein formation, and root development, are explored. Molecular perspectives delve into the intricate gene expression patterns, focusing on the roles of the impact of magnetic field exposure (MFE) on the transcriptomes of different plant species. Furthermore, recent findings on linoleic acid metabolism in collards and tomato seeds provide insights into the complex molecular dynamics triggered by magnetic field exposure (MFE). However, controversies and conflicting findings in the literature are addressed, emphasizing the need for comprehensive models that consider species, genotype, treatment duration, and culture medium. The review concludes by underscoring the importance of novel research paradigms to disentangle plant responses' multifaceted and often contradictory nature to magnetic fields across phenomic, genomic, and molecular levels. Understanding the complex relationship between plants and magnetic fields is essential for advancing our knowledge of these fields' significant impact on plant development. This comprehension is crucial for unravelling the intricate interplay and exploring how magnetic field exposure protocols can be utilized to enhance agricultural production.

Introduction

The geomagnetic field (GMF), an inherent component of our environment, has influenced all living organisms throughout evolution. Consequently, investigating the impact of magnetic fields on organisms has become a focal point for researchers. As responsive entities to diverse environmental stimuli, plants undergo molecular alterations manifesting in observable physiological and physical changes during growth and development. This mini review explores the multifaceted relationship between Earth's magnetic field (MF) and plant behaviour from historical perspectives to contemporary research.

Historical Insights and Experimental Setup

In the early 1960s, the seminal work of Krylov and Tarakonova [1] proposed an auxin-stimulated growth response in germinating seeds attributed to magneto tropism. Subsequent studies, such as those by Boe and Salunkhe [2], extended this phenomenon to describe a ripening effect in tomatoes. Audus and Whish [3] further contributed by exposing plant organs to magnetic fields, unravelling insights into the mechanism of gravity perception in plants. Classifying weak or low magnetic fields (0.5mT to 100nT) and higher intensities paved the way for controlled experiments in research laboratories. Utilizing shielding with high magnetic-permeable ferromagnetic metal plates and compensating with Helmholtz coils became a common practice, enabling the exploration of plant responses to varying magnetic field intensities.

Phenotypic Responses: Growth and Productivity

Numerous reports indicate that plants exhibit significant growth and productivity in response to magnetic fields. Sweet pepper (*Capsicum annuum L.*) seeds exposed to 57-60mT showed increased germination rates and percentages, increased fruit quality, faster growth rates, and higher phosphorus and vitamin C [4]. Similarly, snow peas (*Pisum sativum var. saccharatum*) and chickpeas (*Cicer arietinum L.*) significantly improved the emergence rate index, shoot dry weight, and nutrient content after magnetic treatment [5]. It is also suggested that magnetic field exposure (MFE) may have implications on overall plant health [6], protein formation, and root development [7,8]. MFE was associated with increased production of moieties, chlorophyll contents, and reactive oxygen species-scavenging enzymes in soybeans (*Glycine max*) [9]. The elongation of pea (*Pisum sativum*) epicotyls, most evident in the middle portion, was promoted by low-intensity magnetic fields [10]. Emerging data indicate that applying distinct magnetic field frequencies might modulate fruiting and macronutrient production in the garden strawberry (*Fragaria × ananassa cv. camarosa*) [11].

Molecular Perspectives: Gene and Metabolic Expression Patterns

Plant developmental processes, initiated at the molecular level, prompt an investigation into the effect of MFE on gene expression patterns. Despite numerous reports focusing on biological responses after exposure to electromagnetic fields (EMF), understanding modifications in gene expression patterns remains limited. In *Arabidopsis*, CRY1 and CRY2 genes encoding cytochrome receptors are central to processes involving blue light regulation, flowering, root growth, plant height, and pathogen defense [12]. The geomagnetic effect of a near-null magnetic field in *Arabidopsis* plants resulted in significant changes in the expression patterns of cryptochrome signaling-related genes PHYB, CO, and FT [13]. In cry1/cry2 mutants, the levels of the four identified gibberellins (GAs) in fruits exposed to near-null magnetic fields showed no significant differences compared to controls. The downregulation of GA20-oxidase (GA20ox) genes (GA20ox1 and GA20ox2) and GA3-oxidase (GA3ox) genes (GA3ox1 and GA3ox3) in fruit occurred in wild-type plants rather than cry1/cry2 mutants under the influence of the near-null magnetic field. Conversely, the near-null magnetic field did not impact the expressions of GA2oxidase (GA2ox) genes and GA signaling genes. These findings suggest that the near-null magnetic field-induced suppression of fruit growth is mediated by cryptochrome, and GAs regulate fruit growth in response to this magnetic field condition [14]. Whole genome microarray analysis exposed *Arabidopsis* plants to radiofrequency electromagnetic fields (RFEF) for 24 hours, revealing differential expression patterns in a few transcripts yet an inconclusive molecular response [15]. *Arabidopsis* responses to the Geomagnetic Field (GMF) were evaluated through a transcriptomic time-course analysis using gene microarray technology. Arabidopsis seedlings were grown vertically in Petri dishes and exposed to Near Null Magnetic Field (NNMF) conditions for 10 minutes to 96 hours. Nine genes exhibiting significant expression (< 0.05) and fold changes > 2 were identified. Functional characterization of these genes revealed involvement in hydrolase activity (At1g56680, At1g66270, At1g66280), binding activity (At1g74500, At5g66280, At2g25980), transporter activity (At5g50800), seed storage (At2g37870), and one gene with an unknown function (At2g41800) [16]. Recent research has revealed a marked upregulation of linoleic acid metabolism in collards (Brassica oleracea var. viridis) and tomato (*Solanum lycopersicum*) seeds subjected to a specific low-intensity magnetic field (4.7 Gauss) for 2 hours within six days [17]. This observation suggests the potential of species-specific magnetic field exposure (MFE) protocols to stimulate the production of valuable bioactive compounds, opening new avenues for agricultural bioengineering. Despite these studies, plant responses to magnetic field exposure (MFE) at various intensities have been controversial.

Controversies and Conflicting Findings

While numerous studies have championed the positive effects of MFE on plants, controversies inevitably arise when conflicting findings emerge. *Tkalec, et al*. [18] reported decreased growth in plants exposed to specific electromagnetic field strengths while flowering in *Arabidopsis spp*. was delayed under a near-null magnetic field. A measurable decrease in the fresh weight of shoots and roots and the dry weight of shoots and roots were displayed in barley (*Hordeum vulgar*) after MFE at a relatively low intensity [19]. *In-vitro* studies on MFE to Solanum spp. showcased species dependent responses, emphasizing the intricate interplay of species, genotype, initial explant, treatment duration, and culture medium. Various exposure periods were investigated, revealing contrasting effects on the growth of roots, stems, and leaves in vitro after 14 or 28 days. Notably, one experiment demonstrated a significant increase in leaf growth at the biochemical level, with the quantities of chlorophyll a, chlorophyll b, and carotenoids showing more than a two-fold increase [20]. Therefore, it is justified to pursue the creation of more comprehensive models that elucidate the impact of Magnetic Field Exposure (MFE) across phenomic, genomic, and molecular levels.

Conclusion

This review comprehensively integrates historical knowledge, phenotypic observations, and molecular insights to elucidate the impact of magnetic fields (MFE) on plant development. The multifaceted and often contradictory nature of plant MFE responses highlights the necessity for novel research paradigms. By delving into the molecular intricacies, untangling actual MFE effects from phenome to metabolome and genome is critical to illuminating the intricate interplay between plants and magnetic fields.

References

1. Krylov A, Tarakonova GA (1960) Plant physiology. Fiziol Rost 7: 156.

2. Boe AA, Salunkhe DK (1963) Effects of magnetic fields on tomato ripening. Nature 199: 91-92.
3. Audus LJ, Whish JC (1964) Magnetotropism. In: Barnothy M.F. (eds) Biological Effects of Magnetic Fields. Springer, Boston, MA.
4. Ahamed MEM, Elzaawely AA, Bayoumi YA (2013) Effect of Magnetic Field on Seed Germination, Growth and Yield of Sweet Pepper (Capsicum annuum L). Asian Journal of Crop Science 5: 286-294.
5. Grewal HS, Maheshwari BL (2011) Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances seedlings' early growth and nutrient contents. Bioelectromagnetic 32(1): 58-65.
6. Fu E (2012) The effects of magnetic fields on plant growth & health Young Scientists Journal 11: 38-42.
7. Aladjadjiyan A (2002) Study the influence of magnetic field on some biological characteristics of Zea mais. Journal of Central European Agriculture 3(2): 89-94.
8. Rãcuciu M, Creangã D, Horga I (2006) Plant growth under static magnetic field influence. Phys 53(1-2): 353-359.
9. Asghar T, Jamil Y, Iqbal M, Zia-Ul-Haq, Abbas M (2016) Laser light and magnetic field stimulation effect on biochemical, enzymes activities and chlorophyll contents in soybean seeds and seedlings during early growth stages. J Photochem Photobiol B 165: 283-290.
10. Negishi Y, Hashimoto A, Tsushima M, Dobrota C, Yamashita M, et al. (1999) Growth of pea epicotyl in low magnetic field implication for space research. Advances in Space Research 23(12): 2029-2032.
11. Eşitken A, Turan M (2004) Alternating magnetic field effects on yield and plant nutrient element composition of strawberry (Fragaria x ananassa cv. camarosa) Acta Agriculturae Scandinavica, Section B Soil & Plant Science 54(3): 135-139.
12. Yu X, Liu H, Klejnot J, Lin C (2010) The Cryptochrome Blue Light Receptors. Arabidopsis Book 8: e0135.
13. Xu CX, Wei SF, Lu Y, Zhang YX, Chen, CF, Song T (2013) Removal of the local geomagnetic field affects reproductive growth in Arabidopsis. Bioelectromagnetic 34(6): 437-442.
14. Xu C, Feng S, Yu Y, Zhang Y, Wei S (2021) Near-Null Magnetic Field Suppresses Fruit Growth in Arabidopsis. Bioelectromagnetic 42(7): 593-602.
15. Engelmann JC, Deeken R, Müller T, Nimtz G, Roelfsema MRG, et al. (2008) "Is gene activity in plant cells affected by UMTS-irradiation? A whole-genome approach," Advances and Applications in Bioinformatics and Chemistry 1: 71-83.
16. Paponov IA, Fliegmann J, Narayana R, Maffei ME (2021) Differential root and shoot magnetoresponses in Arabidopsis thaliana. Sci Rep 11(1): 9195.
17. Lockett A, Bernard GC, Asundi S, Mitchell I (2023) Deciphering hidden mechanisms in the biomagnetic response in plants: a study on the effects of magnetic fields on plant growth, development, and molecular responses. (Unpublished manuscript). Dept. of Ag. Envr. And Nutr. Sciences, Tuskegee University.
18. Tkalec M, Malarić K, Pevalek Kozlina B (2005) Influence of 400, 900, and 1900 MHz electromagnetic fields on Lemna minor growth and peroxidase activity. Bioelectromagnetic 26: 185-193.
19. Lebedev SI, Baranskiy PI, Litvinenko LG, Shiyan LT (1977) Barley growth in superweak magnetic field. Electron. Treat. Mater. 3: 71-73.
20. Rakosy Tican L, Aurori CM, Morariu VV (2005) Influence of near null magnetic field on in vitro growth of potato and wild Solanum species. Bioelectromagnetics 26(7): 548-557.