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MAGNETIC FIELD AS A GROWTH ENHANCER: EVALUATING ITS POSITIVE IMPACTS ON AGRONOMIC CHARACTERISTICS OF MING ARALIA (*Polyscias fruticosa*)

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Abstract. This study investigated the effects of a magnetic field (MF) on agronomical and physiological characteristics of Ming aralia (*Polyscias fruticosa*) under hydroponic conditions. The evaluation focused on key root-related traits, including root length, root hair density, fresh biomass, and dry biomass, as well as leaf-related traits such as leaf area, chlorophyll content, and fresh and dry leaf biomass. Results revealed that MF exposure significantly enhanced root development, with treated plants showing a 21.5% increase in root length, a 48.2% improvement in root hair density, 24.8% and 36% higher fresh and dry root biomass, respectively, compared to the control group at day 50 of treatment. Similarly, leaf traits exhibited substantial improvements with MF treatment, including a 20.2% increase in leaf area and a 20.4% enhancement in chlorophyll content by the end of the experiment. Fresh and dry leaf biomass of the treated group were also 25.2% and 28.1% higher, respectively, than those of the control group. These findings suggested that MF acts as a biophysical stimulus, enhancing both morphological and physiological aspects of plant growth, likely by improving water and nutrient absorption, photosynthetic efficiency, and metabolic processes. The study highlights the potential of MF as a sustainable and effective tool to optimize plant development and productivity in controlled cultivation systems.

Keywords: magnetic field, Ming aralia, hydroponic, root, leaf.

1. Introduction

Ming aralia (*Polyscias fruticosa*), a perennial plant species of the family Araliaceae, is native to tropical Asia, particularly India and Southeast Asia [1] and has been widely cultivated for its ornamental, medicinal, and ecological values [2]. *P. fruticosa* has significant pharmacological potential, with traditional medicinal uses ranging from treating inflammation and digestive disorders to promoting general health through its bioactive compounds [3], such as saponins and flavonoids [3], [4]. Cultivation of Ming aralia requires well-drained soil, moderate sunlight, and regular watering, making it suitable for diverse agro-climatic conditions. A deeper understanding of this species is crucial for exploring its therapeutic applications [2], [5], [6], improving its agronomic performance [5], and conserving its genetic diversity amidst increasing environmental and anthropogenic pressures. Investigating the physiological and biochemical responses of *P. fruticosa* under varying conditions could further enhance its utility in sustainable agriculture and medicinal research. In addition to its medicinal uses, Ming aralia is an ideal candidate for agricultural and physiological research due to its adaptability to diverse environmental conditions and ease of propagation. It thrives in well-drained soils, moderate sunlight, and controlled environments such as hydroponic systems, making it a robust species for experimental cultivation. These attributes, combined with its economic and medicinal significance, make Ming aralia a promising model for investigating novel growth-enhancing technologies.

Recently, the application of magnetic fields (MFs) in crop cultivation has emerged as a promising technique to enhance plant growth and development by influencing physiological and biochemical processes [7]-[10]. Positive effects of MF exposure include increased seed germination rates [8], improved nutrient uptake [11], enhanced photosynthetic efficiency [9], and accelerated biomass accumulation [7], [8]. Various crop species, including soybean (*Glycine max*), chickpea (*Cicer arietinum*), wheat (*Triticum aestivum*), tomato (*Solanum lycopersicum*), maize (*Zea mays*), and rice (*Oryza sativa*), have demonstrated significant growth improvements under optimized MF conditions [12]-[16]. Previous studies indicated that a magnetic flux density of 150 milliTesla (mT) is particularly effective for many higher plant species, promoting better stress tolerance and productivity [15]. However, there is limited information on how medicinal plants like *P. fruticosa* respond to MF exposure. The study of Ming aralia and its potential response to MF exposure represents an intersection of traditional botanical significance and modern agricultural innovation. While Ming aralia has long been valued for its medicinal properties [2], exploring the application of MFs provides a novel approach to enhancing its growth and development. Given the proven benefits of MFs in various crops, it is reasonable to hypothesize that similar treatments could unlock new agronomical potential in *P. fruticosa*.

This study aimed to evaluate the effects of MFs on the agronomical and physiological characteristics of Ming aralia plants under hydroponic conditions. Specifically, the study focused on assessing key parameters related to root and leaf development, including root length, root hair density, fresh and dry root biomass, leaf area, chlorophyll (Chl) content, as well as fresh and dry leaf biomass. By systematically comparing these traits between MF-treated and control groups, the study aimed to elucidate the potential of MFs as a biophysical stimulus to enhance plant growth and productivity. The findings seek to provide insights into the physiological mechanisms underlying MF-induced growth responses and contribute to the development of sustainable approaches for optimizing plant performance in controlled cultivation systems.

2. Content

2.1. Materials and methods

2.1.1. Plant materials

The plant materials used in this study were small-leaf Ming aralia collected from the Center of Experimental Biology, Faculty of Agricultural Technology, University of Engineering and Technology, Hanoi City, Vietnam. Stems selected for the experiment were mature, with brown bark and a diameter ranging from 1 to 2 cm. The stems were cut into 15 - 20 cm long segments, each containing at least three nodes to ensure propagation potential.

2.1.2. Methods

Growth condition: The experiment was conducted in a controlled environment with a temperature of 25 ± 2 °C, relative humidity of 60 - 70%, and a 12-hour photoperiod using fluorescent light (200 μmol m^{-2} s^{-1}) as previously experienced.

Hydroponic system setup: The hydroponic cultivation of Ming aralia stems was established using a deep water culture system as previously described [17], designed to support 10 stems and provide a compact yet efficient setup for optimal growth. The reservoir dimensions are 45 cm in length, 20 cm in width, and 15 cm in height, providing a total volume of approximately 13.5 liters. The plants were grown in a hydroponic system using a Hoagland nutrient solution. The solution was maintained at a pH of 5.5 - 6.0 and an electrical conductivity of 1.8 - 2.0 mS/cm. The nutrient solution was replaced every seven days to ensure consistent nutrient availability. The roots were submerged in the solution, which was aerated continuously using an air pump to maintain oxygenation and prevent stagnation.

Magnetic field treatment: The MF treatment was applied using a magnet that produced a uniform magnetic flux density of 150 mT, as previously described [15]. The control group was grown under identical conditions to the treated group, without exposure to the MF. The experiment lasted 50 days, during which plant growth parameters were monitored and recorded at 0, 10, 20, 30, 40, and 50 days after treatment.

Measurements and data collection: Several agronomical characteristics of plant roots and leaves were evaluated throughout the experiment. Root length (cm) was measured using a ruler, and root hair density (number/mm^2) was determined microscopically. Leaf area (cm^2) was measured using a leaf area meter, and chlorophyll content (SPAD units) was assessed using a portable Soil Plant Analysis Development (SPAD) chlorophyll meter. Fresh and dry biomass of roots or leaves (g) were recorded by weighing freshly harvested roots/leaves and oven-drying them at 70 °C to a constant weight.

Statistical analysis: The data were analyzed using a two-way analysis of variance (ANOVA) to determine the significant effects of MF treatment and the treatment duration on the measured traits. Mean values were compared using Tukey's post-hoc test, with a significance level set at $p < 0.05$. All statistical analyses were performed using SPSS software [18].

2.2. Results and discussion

2.2.1. Evaluation of changes in root-related agronomic characteristics of Ming aralia plants under magnetic field treatment

To gain insights into the physiological changes of Ming aralia plants under MF treatment, its effects on root-related agronomic characteristics were assessed. The results revealed significant improvements in root length, root hair density, fresh and dry root biomassthroughout the experimental period.

The treated plants consistently exhibited greater root length than the control group (Figure 1A). On day 0, both groups showed nearly identical root lengths (3.128 cm for the treated group and 3.110 cm for the control group). By day 10, the root length of the treated plants reached 5.411 cm, 10.4% higher than the control group (4.900 cm), with p-value > 0.05. This trend continued throughout the experiment, with the treated group reaching 18.365 cm at day 50, a 21.5% improvement over the control group (15.110 cm). Regarding root hair density, MF exposure significantly enhanced the development of root hairs (Figure 1B). While neither group had measurable root hairs at day 0, by day 10, the treated plants exhibited 2.33 root hairs/mm^2 compared to 1.41 root hairs/mm^2 in the control group, representing a 65.2% increase. By day 50, the treated plants achieved a density of 14.57 root hairs/mm^2, 48.2% higher than the control group, which recorded 9.83 root hairs/mm^2. Similarly, the fresh biomass of roots also showed marked differences (Figure 1C). At day 0, the fresh biomass was nearly identical (0.511 g for the treated group and 0.505 g for the control). By day 10, the treated plants had 1.468 g of fresh biomass, 29.6% higher than the control group (1.133 g). By day 50, the fresh biomass of the treated plants reached 9.908 g, significantly surpassing the control group's 7.937 g, indicating a 24.8% improvement. Similar trends were observed for root dry biomass (Figure 1D). On day 0, the dry biomass in both groups was nearly identical, with 0.084 g in the treated group and 0.081 g in the control group. By day 10, the treated plants recorded 0.313 g, a 36% increase compared to the control group's 0.230 g. At the end of the experiment (day 50), the treated plants achieved a dry biomass of 2.883 g, which was 36% higher than the control group's 2.121 g. These results demonstrate that MF exposure significantly enhances root growth and development in Ming aralia plants (Figure 2). The increased root length and hair density suggest improved water and nutrient absorption capacity, while the higher fresh and dry biomass indicates greater resource allocation and metabolic efficiency in root tissues. Collectively, these findings highlight the potential of MFs as a biophysical stimulus to optimize root system development and overall plant performance.

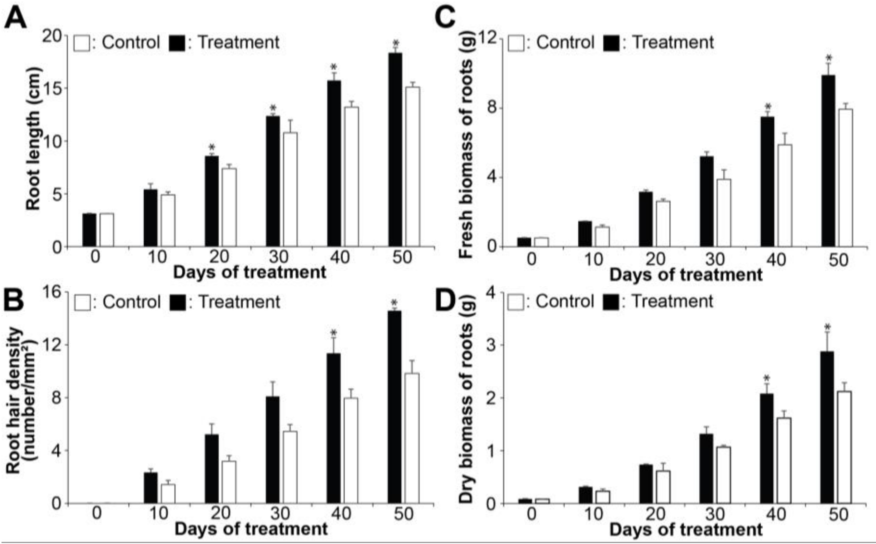

Figure 1. Changes in general root characteristics of Ming aralia plants under magnetic field treatment, including (A) root length, (B) root hair density, (C) fresh biomass, and (D) dry biomass. The asterisk (*) represents a significant change in the MF treatment compared to the control, as determined by the statistical analysis (p< 0.05)

Figure 2. Observation of Ming aralia plants grown under the magnetic field treatment (left) and control conditions (right)

The observed enhancements in root-related characteristics of Ming aralia plants under MF exposure align with previous studies that have documented the positive effects of MFs on root growth and development across various plant species. Research by Atak et al. (2007) demonstrated that magnetic field treatment significantly increased root length and biomass in soybeans, which was attributed to improved cell division and elongation in the root meristem [12]. It has been reported that enhanced root development in rice seedlings subjected to MFs was likely due to increased metabolic activity and nutrient uptake efficiency [16]. Moreover, Vashisth and Nagarajan (2008) found that MF exposure stimulated root hair formation and length in chickpeas, linked to improved water absorption and nutrient acquisition under stress conditions [19]. These studies suggested that MFs improve root system architecture and functionality by influencing cellular processes such as ion transport, enzyme activation, and hormonal signaling. The consistent findings across different species, along with the results of the present study, reinforce the potential of MFs as a sustainable tool for enhancing root growth and productivity, particularly in controlled cultivation systems or resource-limited environments [7]-[10].

2.2.2. Evaluation of changes in leaf-related agronomic characteristics of Ming aralia plants under magnetic field treatment

To evaluate the effects of MF on leaves, several traits were assessed, including leaf area, Chl content, and fresh and dry biomass. The analysis of MF's influence on the leaf area of Ming aralia plants revealed significant differences between the treated and control groups across the experimental period from day 30 (Figure 3A). At the onset of the study (day 0), the leaf area in both groups were similar, with the MF group measuring 1.500 cm^2 and the control group 1.460 cm^2, indicating uniform initial conditions. By day 10, the MF treatment resulted in a leaf area of 2.150 cm^2, compared to 1.820 cm^2 in the control group, showing a 15.7% increase in the treated plants. This trend continued over time, with the MF group achieving a leaf area of 3.000 cm^2 on day 20, which was 34.5% larger than the 2.230 cm^2 observed in the control. By day 30, the leaf area of the treated plants reached 3.720 cm^2, significantly outpacing the control's 2.780 cm^2, marking a 33.8% increase. On day 40, the MF group displayed a leaf area of 4.540 cm^2, compared to 3.330 cm^2 in the control, representing a 36.4% enhancement. By day 50, the MF-treated plants exhibited a leaf area of 4.990 cm^2, surpassing the control group's 4.150 cm^2 by 20.2%. These results suggest that exposure to an MF significantly promotes leaf area expansion in Ming aralia plants, potentially enhancing their photosynthetic capacity.

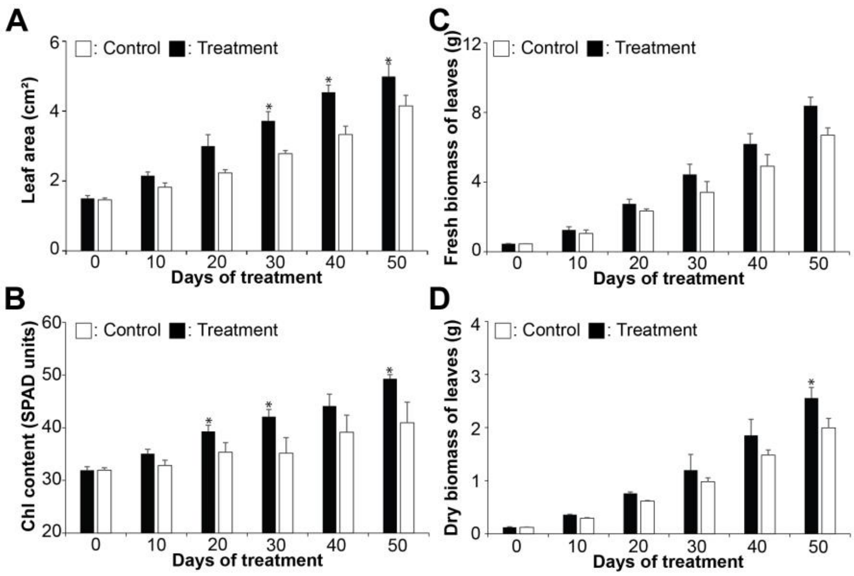

Figure 3. Changes in leaf general features of Ming aralia plants under the magnetic field treatment, including (A) leaf area, (B) chlorophyll content, (C) fresh biomass, and (D) dry biomass. The asterisk (*) represents a significant change in the treatment compared to the control ($p < 0.05$)

Next, we evaluated the effects of MF on Chl content in Ming aralia plants grown under hydroponic conditions (Figure 3B). At the start of the experiment, the Chl content in both groups were nearly identical, with the MF group at 31.914 SPAD units and the control group at 31.928 SPAD units, indicating a uniform baseline. By day 10, the Chl content of the MF-treated plants increased to 35.050 SPAD units, compared to 32.842 SPAD units in the control group, representing a 6.7% increase. The trend persisted through day 20, with the treated group reaching 39.27 SPAD units, 11.1% higher than the control at 35.35 SPAD units. By day 30, the MF treatment resulted in a Chl content of 42.08 SPAD units, a 19.7% increase over the control group (35.15 SPAD units). On day 40, the treated plants reached 44.11 SPAD units, while the control group had 39.15 SPAD units, showing a 12.7% improvement. On day 50, the treated group exhibited a Chl content of 49.283 SPAD units, surpassing the control group’s 40.950 SPAD units by 20.4%. These results demonstrated that MF exposure significantly enhances Chl synthesis in Ming aralia plants, potentially improving their photosynthetic efficiency and overall physiological performance. Previously, the enhanced Chl content observed in the MF-treated plants was closely linked to improvements in leaf area development. [11], [15], [20]. As chlorophyll plays a vital role in photosynthesis, the increased Chl content observed in the treated plants likely contributed to their enhanced ability to expand leaf surface area. This synergistic effect between Chl synthesis and leaf growth highlights the comprehensive influence of MFs on both plant physiological and morphological traits.

Additionally, the evaluation of the effects of MFs on the fresh and dry biomass of leaves in Ming aralia plants revealed a similar phenomenon throughout the study period. Both groups started at comparable levels for fresh biomass on day 0, with the MF group measuring 0.465 g and the control group 0.451 g. An increase in leaf fresh biomass was observed at each time point analyzed, however, this increase was not statistically significant (Figure 3C). Similar patterns were observed with leaf dry biomass. There was no significant increase in leaf dry biomass of the MF-treated group compared to the control from day 10 to day 40. However, at the end of the experiment (day 50), the MF-treated plants showed a significant increase of 28.1% with a dry biomass of 2.555 g compared to the control's 1.995 g (Figure 3D). These findings indicate that exposure to MFs substantially enhances fresh and dry biomass accumulation in the leaves of Ming aralia plants. The consistent improvement at several time points highlights the positive impact of MF treatments on the physiological growth and resource allocation of the plants. Together, these findings emphasize MF treatments' potential to optimize photosynthetic capacity and overall plant development, providing a strong foundation for integrating this approach into modern cultivation practices. The findings highlight the efficacy of MF treatments in improving agronomical traits, making it a promising strategy for optimizing plant productivity.

The findings of this study align with previous research on the effects of MFs on leaf development in plants [7]-[9]. Several studies have reported that MFs enhanced biomass accumulation across multiple crop species, such as wheat [21], maize [15], [22], and tomato [14]. Among them, Chl synthesis and photosynthetic efficiency under MFs treatment have also been well-documented. Previous studies have shown that MF exposure can increase Chl content and improve photosynthetic performance by influencing key enzymes involved in chloroplast development. For example, it has been demonstrated that MF treatments increased the Chl content and photosynthetic rate in rice [16], resulting in higher yield and biomass. These results are consistent with the enhanced Chl content observed in Ming aralia plants in this study, suggesting that MFs stimulate photosynthetic machinery, ultimately supporting more significant plant growth. Furthermore, the observed increases in leaf area and biomass in this study also align with previous findings on the morphological impacts of magnetic fields. Particularly, it has been reported that MF exposure significantly increased leaf expansion and biomass production in soybeans [10], [12], [23], which was linked to enhanced water absorption and nutrient uptake facilitated by MF. This mechanism likely underpins the increases in leaf area observed in Ming aralia plants, as MFs may influence ion transport and membrane permeability, thereby improving resource acquisition and utilization. Overall, our results highlight the potential of MFs as a non-invasive and energy-efficient method to enhance plant growth and development. Future research should focus on evaluating long-term effects, optimal MF parameters for different species, and the scalability of this technique for agricultural applications.

3. Conclusions

In summary, this study comprehensively evaluated the effects of MF on the agronomic characteristics of Ming aralia plants, focusing on root- and leaf-related traits under hydroponic conditions. The results demonstrated that MF exposure significantly enhances root length, root hair density, and both fresh and dry root biomass. Treated plants consistently outperformed controls, with increases of up to 21.5% in root length, 48.2% in root hair density, 24.8% in fresh root biomass, and 36% in dry root biomass by the end of the experimental period. Similarly, MF exposure positively affected leaf-related traits, including leaf area, chlorophyll content, and biomass. By day 50, leaf area in MF-treated plants increased by 20.2% compared to controls, while chlorophyll content improved by 20.4%. These increases suggest enhanced photosynthetic capacity, likely driven by synergistic effects of chlorophyll synthesis and leaf expansion. Furthermore, fresh and dry biomass accumulation in leaves was slightly higher in MF-treated plants, with increases of 25.2% and 28.1%, respectively, by the end of the experiment. These findings revealed that MFs act as a biophysical stimulus to improve both root and leaf development in Ming aralia plants, enhancing their growth and productivity.

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