

# EVALUATION OF THE EFFECTS OF MAGNETIC FIELD TREATMENT ON THE GERMINATION AND VEGETATIVE GROWTH OF SOYBEAN (*GLYCINE MAX*) IN COLD CONDITIONS

Than Gia Bao<sup>1</sup>, Nguyen Duc Hai<sup>2</sup>, Dong Huy Gioi<sup>1</sup>, La Viet Hong<sup>3</sup>,  
Le Thi Ngoc Quynh<sup>4</sup>, Chu Duc Ha<sup>2\*</sup>, Le Huy Ham<sup>2</sup>

<sup>1</sup>Vietnam National University of Agriculture, Hanoi

<sup>2</sup>University of Engineering and Technology, Vietnam National University Hanoi, Hanoi

<sup>3</sup>Hanoi Pedagogical University 2, Phu Tho

<sup>4</sup>Thuyloi University, Hanoi

Received: 11 September 2025; Revised: 18 September 2025; Accepted: 22 September 2025  
DOI: <https://doi.org/10.59775/1859-3968.344>

## Abstract

Soybean (*Glycine max* L.) is vulnerable to cold stress during germination and early vegetative growth, leading to poor establishment and reduced productivity. This study examined the potential of static magnetic field (MF) treatment to enhance cold tolerance in the Vietnamese soybean variety DT84. Seeds were exposed to a static MF before sowing and evaluated under both optimal and low-temperature conditions. Results showed that MF treatment improved germination dynamics, reduced abnormal seedlings, and enhanced seedling vigor under cold stress. During vegetative development, MF-treated plants exhibited greater emergence, improved hypocotyl elongation, larger leaf area, increased plant height, stronger root systems, higher biomass accumulation, and greater chlorophyll content compared with untreated controls. Although the treatment did not fully restore growth to the level observed at optimal temperature, it consistently alleviated the inhibitory effects of cold stress and narrowed the performance gap across developmental stages. These findings indicate that MF treatment is a simple, low-cost, and environmentally sustainable approach to improve soybean establishment under cold conditions and holds promise as a practical strategy for enhancing crop resilience in early-season sowing.

**Keywords:** Soybean, cold stress, magnetic field, germination and growth.

## 1. Introduction

Soybean (*Glycine max* L.) is a strategic source of plant protein and vegetable oil and a key component of global food, feed, and bioeconomy value chains [1]. Successful stand establishment and early vegetative growth underpin final yield and quality.

Low temperature threatens these stages in temperate and subtropical regions and during early-season cold spells [2]. Cold stress delays radicle protrusion, slows hypocotyl and root elongation, and restricts leaf expansion. Cellular injuries arise from membrane phase transitions, impaired enzyme kinetics, and an imbalance between abscisic acid and

\*Email: cd.ha@vnu.edu.vn

gibberellin. Oxidative stress follows because reactive oxygen species accumulate faster than antioxidant systems can remove them. Photosystem II suffers photoinhibition under low temperature with light. Nutrient uptake declines, and phloem loading becomes inefficient [3]. These processes converge on weaker seedlings, heterogeneous canopies, and persistent yield penalties.

Magnetic field exposure represents a low-cost, non-chemical intervention with growing evidence in crop science [4]. Both static magnetic fields and pulsed electromagnetic fields have shown benefits in cereals, vegetables, and legumes at intensities commonly between tens and a few hundred millitesla [5]. Reported effects include faster water uptake in dry seeds, higher activities of key hydrolytic and antioxidant enzymes, improved ion transport, and enhanced photosynthetic performance [6]. Mechanistic explanations reference radical-pair reactions, modulation of calcium signaling, stabilization of membranes, and transcriptional shifts in stress-response pathways. Magnetic pretreatment of seeds and early seedling exposure integrates easily with standard nursery or laboratory protocols, requires modest equipment, and leaves no chemical residues [7]. Responses often follow dose and time “windows,” which underscores the need for crop- and stage-specific optimization.

The present study investigates whether exposure to a static magnetic field can mitigate cold stress in soybeans during germination and early growth. The objectives are to quantify effects on germination dynamics, seedling vigor, root and shoot development, chlorophyll content, membrane integrity, and antioxidant status under a defined low-temperature regime, and to compare responses between magnetically treated and untreated controls. We hypothesize that static magnetic field treatment improves cold tolerance in soybean and yields measurable gains in early growth and physiological traits.

## 2. Method

### 2.1. Plant material and seed preparation

Seeds of the Vietnamese soybean variety DT84, developed by the Agricultural Genetics Institute (Viet Nam) [8], were used in this study. Certified seed lots were obtained from a licensed commercial supplier and produced in the 2023 growing season. According to the supplier’s certificate, the seed lot had a laboratory germination rate of 96% and a moisture content of 10.8% at the time of purchase. Uniform, undamaged seeds were selected by visual inspection before use. Seeds were surface-sterilized in 70% ethanol for 60 s, then rinsed twice with sterile distilled water before immersion in 2% sodium hypochlorite for 10 min as previously described with minor adjustment [9]. After disinfection, seeds were rinsed five times with sterile distilled water to remove residual chlorine. Excess surface moisture was blotted off with sterile filter paper, and seeds were air-dried under sterile laminar flow for 15 min at room temperature ( $25 \pm 1^\circ\text{C}$ ) to standardize moisture conditions before magnetic field exposure. Sterile distilled water served as the wetting medium for all pre-sowing procedures.

### 2.2. Magnetic field treatment

The field strength of the magnetic field at the seed plane was 150 mT and remained stable within  $\pm 2$  mT, as verified with a Gaussmeter before each run as recently reported [10]. Seeds were placed in a single layer in non-metallic Petri dishes and exposed for 30 min at room temperature ( $25 \pm 1^\circ\text{C}$ ). Control seeds were placed in identical dishes outside the field for the same duration.

### 2.3. Cold stress treatment

Cold stress was imposed at  $12^\circ\text{C}$  during both germination and early seedling growth as recently described [3] with minor changes. A programmable growth chamber (Model:

MLR-352H, Sanyo/Panasonic Biomedical, Japan) provided controlled environmental conditions with 12°C during the dark period and 14°C during the light period to emulate a mild diurnal fluctuation. Relative humidity was maintained at  $60 \pm 5\%$ , while the control temperature was 25°C (dark) and 27°C (light). Photosynthetic photon flux density was  $200 \mu\text{mol m}^{-2} \text{s}^{-1}$  at canopy height with a 14 h light/10 h dark photoperiod. Relative humidity was continuously monitored using a digital capacitive humidity probe (Vaisala HMP110, Finland) integrated into the chamber's control system. Calibration was verified against an external hygrometer (Testo 608-H2, Germany) before each experiment. Recorded humidity values remained within the target range throughout all runs, with maximum deviations not exceeding  $\pm 3\%$ . Measurements were verified prior to each run using a digital thermocouple array (Testo 176 T4, Germany) positioned at multiple points across vertical and horizontal planes. Temperature variation did not exceed  $\pm 1.0^\circ\text{C}$  for all replicates throughout the experiment.

#### ***2.4. Soybean cultivation protocol***

Germination occurred in the dark on moistened, sterile germination paper in 15-cm Petri dishes. Each dish received 25 seeds and 7 mL sterile water, and papers were kept moist by periodic addition of sterile water. Germination counts were recorded every 12 h up to 72 h. Seedlings that reached a radicle length of at least 2 mm after 48 hours were transferred to hydroponic culture. Hydroponic cultivation was chosen instead of soil because it provided precise control over nutrient composition, temperature, and moisture. Seedlings grew in opaque polypropylene tubs with floating foam rafts. Each raft had 12 evenly spaced holes that held inert foam plugs supporting seedlings at the collar. The nutrient solution contained half-strength Hoagland medium adjusted to pH  $6.0 \pm 0.1$ . Aeration was supplied continuously through aquarium pumps equipped with sterile

air filters and fine-pore diffusers. Both pH and electrical conductivity were measured daily using calibrated meters (HI9811-5, Hanna Instruments, Italy) and adjusted when necessary. Electrical conductivity remained within  $1.1 - 1.3 \text{ mS cm}^{-1}$ , and the solution temperature followed the chamber's settings. The nutrient solution was replaced every three days. Seedlings developed to the VE - V2 stages under the specified light and temperature conditions [11].

#### ***2.5. Experimental design and treatment structure***

The study employed a factorial arrangement with two magnetic field levels (exposed and unexposed) and two temperature regimes (cold stress and control) in a completely randomized design. Each treatment combination consisted of four biological replicates. Each replicate comprised one independent hydroponic pot block, containing 10 pots per block. Each block was considered a separate experimental unit to verify biological independence. To minimize positional effects within the growth chamber, all pots were re-randomized every 48 hours. Environmental parameters, including temperature, humidity, and light intensity, were continuously monitored to confirm uniform exposure across replicates. Data from individual plants within each replicate were averaged before statistical analysis to represent the mean response of that experimental unit.

#### ***2.6. Measurement of germination and growth parameters***

Germination and early growth were assessed using quantitative parameters that describe seed vigor, seedling morphology, and physiological performance under both optimal and cold stress conditions. All measurements were performed on four biological replicates per treatment. The germination percentage (%) was determined according to the standard

protocol. Seeds were considered germinated when the radicle reached at least 2 mm in length. The percentage was calculated as the ratio of sprouted seeds to the total number of seeds sown, multiplied by 100. Mean germination time (hours) was computed using the formula below: Mean germination time =  $\sum(n_i \times t_i) / \sum n_i$ , where  $n_1, n_2, \dots$  represent the number of seeds germinated at each time interval  $t_1, t_2, \dots$ . Germination counts were recorded every 12 hours up to 72 hours. The germination index was calculated according to the formula below: Germination index =  $\sum (G_t/D_t)$ , where  $G_t$  is the number of seeds germinated on day  $t$  and  $D_t$  is the corresponding day of counting. Radicle length (mm) was measured 7 days after sowing using a digital caliper (Mitutoyo 500-196-30, Japan) with a precision of  $\pm 0.01$  mm. Measurements were taken from the seed junction to the radicle tip and from the seed junction to the shoot apex, respectively. Next, ten seedlings per replicate were blotted to remove surface moisture, and total fresh weight was recorded using an analytical balance (Sartorius Entris II, Germany) with  $\pm 0.001$  g accuracy. Dry weight was determined after oven-drying the samples at  $70^\circ\text{C}$  for 48 hours until a constant weight was achieved. Leaf area was measured at the  $V_2$  and  $V_5$  growth stages using a leaf area meter (LI-3100C, LI-COR Biosciences, USA). The mean value per plant was computed based on three representative trifoliolate leaves. Relative chlorophyll content was estimated *in vivo* using a portable chlorophyll meter (SPAD-502 Plus, Konica Minolta, Japan) by averaging three readings per leaf on the third and fifth trifoliolate leaves. At each vegetative stage, the entire root system was carefully washed and straightened before measurement with a digital caliper (Mitutoyo 500-196-30, Japan).

### 2.7. Statistical analysis

All statistical analyses were conducted using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Data were

analyzed by one-way analysis of variance (ANOVA) with magnetic field exposure. When significant main were detected ( $p$ -value  $< 0.05$ ), Tukey's Honestly Significant Difference (HSD) test was applied for post-hoc pairwise comparisons. Data are presented as mean  $\pm$  standard error based on four biological replicates per treatment combination.

## 3. Results and Discussions

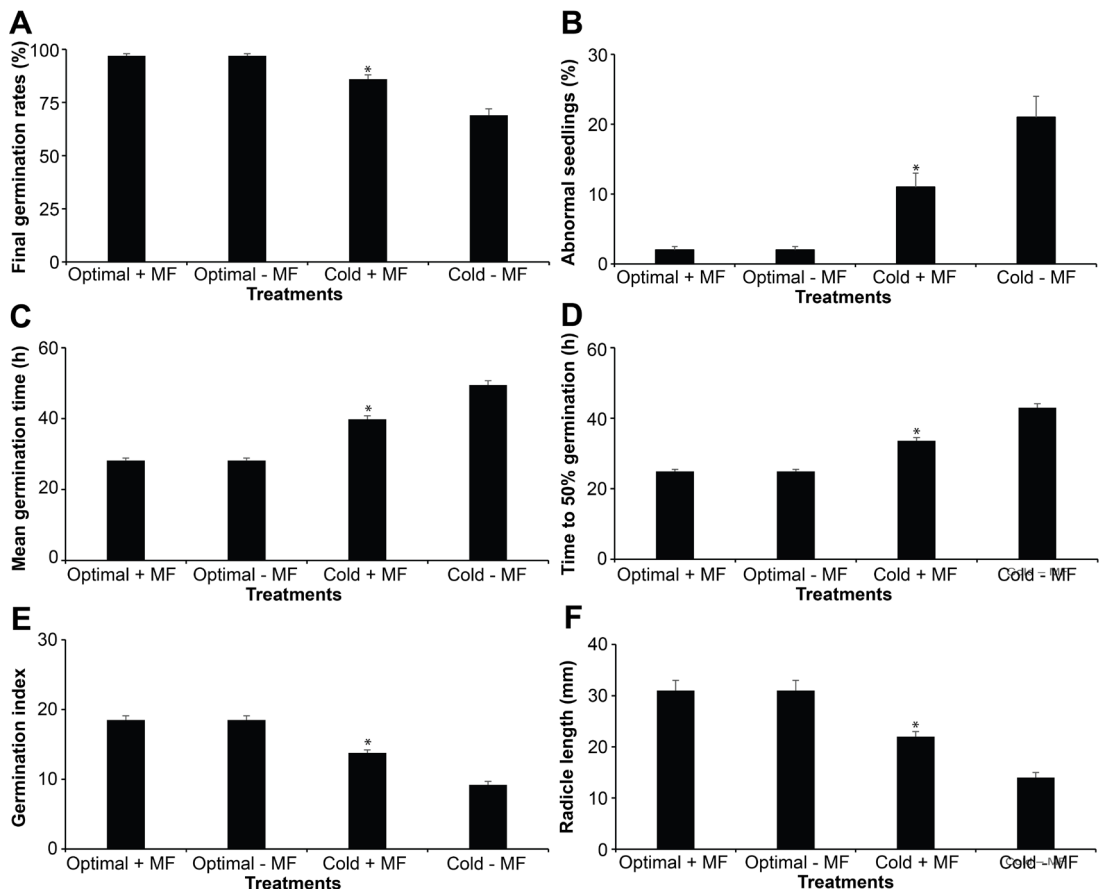
### 3.1. Evaluation of the effect of the magnetic field on the germination process of soybean plants under cold stress

Cold stress clearly reduced the germination ability of DT84 soybean seeds, but exposure to a magnetic field helped lessen this negative effect. Under optimal temperature, both treated and untreated seeds achieved the same high germination rate of  $97 \pm 1\%$ , showing that the magnetic field did not influence normal conditions (Figure 1A). When exposed to cold, however, the germination rate of untreated seeds dropped sharply to  $69 \pm 3\%$ . Seeds treated with a magnetic field still reached  $86 \pm 2\%$  ( $p$ -value  $< 0.05$ ), a clear improvement of 17 percentage points. This result shows that magnetic treatment helped the seeds maintain their ability to germinate despite the low temperature. Cold conditions also caused more abnormal seedlings. The percentage of deformed or weak seedlings rose from  $2 \pm 0.5\%$  under optimal temperature to  $21 \pm 3\%$  under cold stress (Figure 1B). Seeds treated with the magnetic field showed only  $11 \pm 2\%$  abnormal seedlings ( $p$ -value  $< 0.05$ ), which indicates that the treatment helped protect early seedling development and maintained better structural stability during germination. A similar trend has been recorded in mean germination time (Figure 1C). The pace of germination slowed under cold stress. Untreated seeds required  $49.5 \pm 1.2$  hours to finish germination, with a time to 50%

germination of  $43.0 \pm 1.1$  hours (Figure 1D). Under optimal conditions, these values were much shorter, by  $28.2 \pm 0.7$  hours and  $24.9 \pm 0.6$  hours, respectively. When exposed to the magnetic field under cold stress, seeds germinated faster, reaching a mean germination time of  $39.8 \pm 1.0$  hours and a  $T_{50}$  of  $33.6 \pm 0.9$  hours ( $p$ -value  $< 0.05$ ). The germination index also demonstrated this improvement. It fell from  $18.5 \pm 0.6$  under optimal conditions to  $9.2 \pm 0.5$  under cold stress, but magnetic field treatment increased it to  $13.8 \pm 0.4$  (Figure 1E). The same trend appeared in root development. Under

cold stress, the radicle length of untreated seedlings was only  $14 \pm 1$  mm, while treated seeds significantly reached  $22 \pm 1$  mm (Figure 1F). Under optimal temperature, radicle length was  $31 \pm 2$  mm in both groups.

Together, these results support a positive effect of static magnetic field on both the rate and completeness of germination of DT84 soybean under cold stress, with negligible effects at optimal temperature. Our study indicated that static magnetic exposure improved both the rate and the completeness of DT84 germination under cold stress and reduced abnormal seedling formation (Figure 2), while exerting



**Figure 1. Effect of static magnetic field treatment on the germination of soybean under optimal and cold conditions**

(A) Final germination percentage (%). (B) Abnormal seedlings (%). (C) Mean germination time (h). (D) Time to 50% germination ( $T_{50}$ , h). (E) Germination index. (F) Radicle length (mm). Bars represent mean  $\pm$  SE ( $n = 4$ ). Asterisks (\*) indicate significant differences compared with the corresponding cold-stressed control ( $p$ -value  $< 0.05$ ).

no detectable effect at optimal temperature. The findings support a role for magnetic priming as a risk-management tool for soybean establishment in cool conditions, motivating the optimization and mechanistic dissection tailored to DT84.

### ***3.2. Evaluation of the effect of the magnetic field on vegetative growth of soybean plants under cold stress***

Cold stress markedly inhibited vegetative development of DT84 soybean plants from emergence to the fifth trifoliate stage (Figures 3, 4, 5). Magnetic field treatment alleviated this inhibition, resulting in measurable gains in height, leaf development, and biomass accumulation at each growth stage. At emergence and unrolled unifoliate leaves, the emergence rate under cold stress declined to  $72 \pm 3\%$  compared with  $95 \pm 2\%$  in the optimal temperature control. Magnetic field exposure increased emergence to  $86 \pm 2\%$  under cold stress ( $p$ -value  $< 0.05$ ). Hypocotyl length in cold-stressed plants averaged  $4.2 \pm 0.3$  cm without a magnetic field and  $5.8 \pm 0.4$  cm with a magnetic field, compared with  $6.7 \pm 0.3$  cm under optimal temperature. Cotyledon area followed a similar trend, with a 28% reduction under cold stress relative to the optimal temperature, but only a 14% reduction in magnetic field-treated seedlings ( $p$ -value  $< 0.05$ ).

At the first and second trifoliate stages, cold stress reduced plant height to  $6.5 \pm 0.4$  cm at the first trifoliate stage and  $10.8 \pm 0.5$  cm at the second trifoliate stage, compared with  $9.1 \pm 0.3$  cm and  $14.7 \pm 0.4$  cm at optimal temperature. Magnetic field treatment increased plant height under cold conditions to  $8.4 \pm 0.3$  cm at the first trifoliate stage and  $13.2 \pm 0.6$  cm at the second trifoliate stage ( $p$ -value  $< 0.05$ ). Leaf area expansion was similarly affected: cold stress reduced the mean leaflet area by 36% at the second trifoliate stage, while magnetic field-

treated plants showed only a 20% reduction. Specific leaf weight increased under cold stress but was moderated by the magnetic field. From the third to fifth trifoliate stages, the cumulative advantage of magnetic field treatment became more evident. At the third trifoliate stage, shoot fresh weight under cold stress reached  $1.25 \pm 0.08$  g per plant in untreated seedlings, compared with  $1.92 \pm 0.10$  g in magnetic field-treated plants and  $2.35 \pm 0.12$  g at optimal temperature. Root length under cold stress was reduced to  $8.1 \pm 0.5$  cm, while magnetic field exposure increased root elongation to  $11.0 \pm 0.6$  cm (optimal temperature:  $12.7 \pm 0.5$  cm). At the fifth trifoliate stage, cold-stressed plants without a magnetic field averaged  $16.4 \pm 0.7$  cm in height, while magnetic field-treated plants reached  $20.2 \pm 0.8$  cm (optimal temperature:  $23.8 \pm 1.0$  cm). Dry biomass at the fifth trifoliate stage followed the same pattern, with magnetic field-treated plants accumulating 28% more biomass than untreated plants under cold conditions ( $p$ -value  $< 0.05$ ). Chlorophyll content measured at the third and fifth trifoliate stages showed significant improvement with the magnetic field. Under cold stress, untreated plants recorded  $1.42 \pm 0.05$  mg g<sup>-1</sup> fresh weight of total chlorophyll, while magnetic field-treated plants reached  $1.95 \pm 0.06$  mg g<sup>-1</sup> fresh weight (optimal temperature:  $2.18 \pm 0.07$  mg g<sup>-1</sup> fresh weight). This suggests that the magnetic field preserved photosynthetic capacity during cold exposure. Our results indicated that magnetic field treatment consistently improved emergence, early leaf expansion, plant height, root development, biomass accumulation, and chlorophyll content under cold stress. The effect was not sufficient to restore performance to the level observed under optimal temperature, but it significantly reduced the gap, particularly from the second to fifth trifoliate stages, indicating sustained positive influence throughout vegetative development.

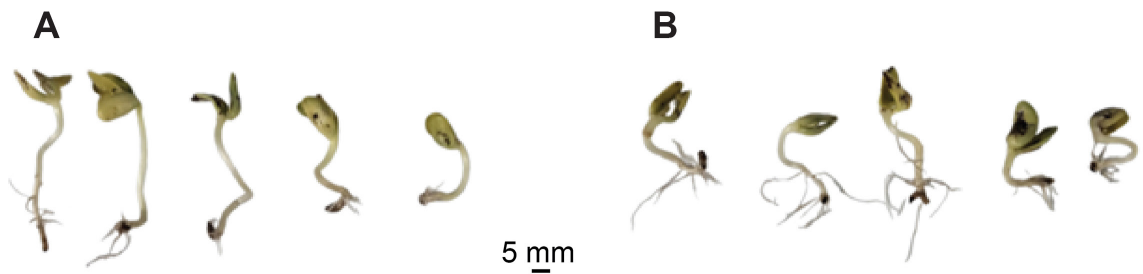


Figure 2. Soybean seedlings at the emergence stage under cold stress. (A) Seedlings derived from magnetic field-treated seeds; (B) seedlings derived from non-magnetic field-treated seeds.



Figure 3. Soybean seedlings at the unrolled unifoliate leaves stage under cold stress. (A) Seedlings derived from magnetic field-treated seeds; (B) seedlings derived from non-magnetic field-treated seeds.



Figure 4. Soybean plants at the first trifoliate stage under cold stress. (A) Plants derived from magnetic field treatment; (B) plants derived from non-magnetic field treatment.



**Figure 5. Soybean plants at the fifth trifoliolate stage under cold stress. (A) Plants derived from magnetic field treatment; (B) plants derived from non-magnetic field treatment.**

The results demonstrate that static magnetic field exposure enhanced vegetative growth of DT84 soybean plants under cold stress, with positive effects observed consistently from the emergence through the fifth trifoliolate stages. Treated plants showed higher emergence rates, longer hypocotyls, greater leaf expansion, and higher biomass accumulation compared with untreated plants under the same cold conditions [12]. Although growth did not fully recover to levels achieved at optimal temperature, the treatment narrowed the performance gap and improved plant establishment during the critical early vegetative phase. Cold stress typically delays emergence, restricts leaf development, and suppresses both shoot and root growth through multiple physiological constraints, including impaired cell division, reduced membrane fluidity, and diminished enzyme activity [13]. The present findings indicate that magnetic field exposure partially counteracted these inhibitory effects. Enhanced hypocotyl elongation and higher emergence suggest improved

seedling vigor, likely linked to earlier water uptake and reduced solute leakage during germination [14]. In later vegetative stages, higher plant height and larger leaf area in treated plants point to better cell expansion and photosynthetic development, consistent with reports that magnetic priming stabilizes cellular membranes and promotes water relations under stress. Root development also benefited from magnetic field exposure. The observed increase in root length under cold stress may reflect improved auxin distribution or enhanced nutrient uptake, both of which are known to be sensitive to membrane transport processes. Stronger root systems would, in turn, support shoot growth and improve biomass accumulation. The higher chlorophyll content recorded in treated plants provides additional evidence that magnetic exposure preserved photosynthetic machinery under low-temperature stress. Similar improvements in chlorophyll concentration and photosynthetic efficiency have been documented in other legumes exposed to magnetic fields, reinforcing

the generality of the response. From an agronomic perspective, the cumulative gains observed at the third to fifth trifoliate stages are particularly important. Uniform emergence, robust leaf expansion, and sustained root growth during early vegetative stages establish a stronger canopy and greater capacity for resource capture, which directly influences later reproductive success and yield potential [10]. Seed magnetopriming represents a simple, low-cost technique that can be applied before sowing without requiring chemical inputs [15]. This makes it especially suitable as a complementary strategy for early-season planting in environments prone to cold stress. Future research should clarify the underlying mechanisms by combining physiological and molecular approaches. Measurements of antioxidant enzyme activity, membrane stability, and hormone profiles would link growth outcomes to stress-mitigation pathways. Gene expression analysis of cold-responsive and photosynthesis-related markers could provide further insight into regulatory changes. Field validation under variable early-season temperatures would confirm the practical value of this approach.

#### 4. Conclusion

This study confirmed that static magnetic field exposure significantly enhanced the germination and early vegetative growth of the Vietnamese soybean variety DT84 under cold stress. Magnetic field treatment improved germination dynamics and seedling vigor, increasing the final germination rate from  $69 \pm 3\%$  to  $86 \pm 2\%$ , reducing abnormal seedlings from  $21 \pm 3\%$  to  $11 \pm 2\%$ , shortening mean germination time by nearly 10 hours, and almost doubling the vigor index ( $96.6 \pm 7.8$  to  $189.2 \pm 9.1$ ). During vegetative development, treated plants exhibited stronger root and shoot growth, with emergence increasing from  $72$

$\pm 3\%$  to  $86 \pm 2\%$ , hypocotyl length from  $4.2 \pm 0.3$  cm to  $5.8 \pm 0.4$  cm, plant height at the first and second trifoliate stages rising to  $8.4 \pm 0.3$  cm and  $13.2 \pm 0.6$  cm, and root length and shoot weight increasing by 36% and 54%, respectively. At the fifth trifoliate stage, plant height improved from  $16.4 \pm 0.7$  cm to  $20.2 \pm 0.8$  cm, dry biomass rose by 28%, and total chlorophyll content increased from  $1.42 \pm 0.05$  mg g<sup>-1</sup> to  $1.95 \pm 0.06$  mg g<sup>-1</sup> fresh weight, reflecting better photosynthetic performance and growth resilience. Although MF treatment did not fully restore performance to the optimal temperature level, it effectively mitigated the inhibitory effects of cold stress, narrowing growth disparities across all stages. These results indicate that magnetic field pretreatment offers a practical, low-cost, and environmentally friendly method to enhance soybean establishment, physiological stability, and early-season cold tolerance, with strong potential for further field validation and mechanistic exploration.

#### References

- [1] Kang J. H., Dong Z., & Shin S. H. (2023). Benefits of soybean in the era of precision medicine: A review of clinical evidence. *Journal of Microbiology and Biotechnology*, 33(12): 1552-1562.
- [2] Tsegaw M., Zegeye W. A., Jiang B., Sun S., Yuan S., Han T., & Wu T. (2023). Progress and prospects of the molecular basis of soybean cold tolerance. *Plants*, 12(3): 459.
- [3] Liu X., Zhang C., Lamloom S. F., Zhao K., Abdelghany A. M., Wang X. & Zhang F. (2024). Genetic adaptations of soybean to cold stress reveal key insights through transcriptomic analysis. *Biology*, 13(11), 856.
- [4] Radhakrishnan R. (2019). Magnetic field regulates plant functions, growth and enhances tolerance against environmental stresses. *Physiology and Molecular Biology of Plants*, 25(5), 1107-1119.
- [5] Afzal I., Saleem S., Skalicky M., Javed T., Bakhtavar M. A., Ul Haq Z. & Kamran M. (2021). Magnetic field treatments improves

- sunflower yield by inducing physiological and biochemical modulations in seeds. *Molecules*, 26(7), 2022.
- [6] Sarraf M. & Kataria S. (2020). Magnetic field (MF) applications in plants: An overview. *Plants*, 9(9), 1139.
- [7] Radhakrishnan R. (2018). Seed pretreatment with magnetic field alters the storage proteins and lipid profiles in harvested soybean seeds. *Physiology and Molecular Biology of Plants*, 24(2), 343-347.
- [8] Thu N. B., Nguyen Q. T., Hoang X. L., Thao N. P., & Tran L. S. (2014). Evaluation of drought tolerance of the Vietnamese soybean cultivars provides potential resources for soybean production and genetic engineering. *BioMed Research International*, 2014(1), 809736.
- [9] Gilbert G. S., Diaz A., & Bregoff H. A. (2023). Seed disinfestation practices to control seed-borne fungi and bacteria in home production of sprouts. *Foods*, 12(4), 747.
- [10] Dziwulska-Hunek A., Niemczynowicz A., Kycia R. A., Matwijczuk A., Kornarzyński K., Stadnik J. & Szymanek M. (2023). Stimulation of soy seeds using environmentally friendly magnetic and electric fields. *Scientific Reports*, 13(1), 18085.
- [11] Palermo M., Paradiso R., De Pascale S. & Fogliano V. (2012). Hydroponic cultivation improves the nutritional quality of soybean and its products. *Journal of Agricultural and Food Chemistry*, 60(1), 250-255.
- [12] Pawelek A., Owusu S. A., Cecchetti D., Zielińska A. & Wyszowska J. (2022). What evidence exists of crop plants response to exposure to static magnetic and electromagnetic fields? A systematic map protocol. *Environmental Evidence*, 11(1), 37.
- [13] Teixeira da Silva J. A. & Dobránszki J. (2016). Magnetic fields: how is plant growth and development impacted? *Protoplasma*, 253(2), 231-248.
- [14] Maffei M. E. (2014). Magnetic field effects on plant growth, development, and evolution. *Frontiers in Plant Sciences*, 5(1), 445.
- [15] Abhary M. K. & Akhka A. (2023). Effects of neodymium magneto-priming on seed germination and salinity tolerance in tomato. *Bioelectromagnetics*, 44(1-2), 47-56.

## ĐÁNH GIÁ TÁC ĐỘNG CỦA TỪ TRƯỜNG ĐẾN NẤY MẦM VÀ SINH TRƯỞNG SINH DƯỠNG CỦA ĐẬU TƯƠNG (*Glycine max*) TRONG ĐIỀU KIỆN LẠNH

Thân Gia Bảo<sup>1</sup>, Nguyễn Đức Hải<sup>2</sup>, Đồng Huy Giới<sup>1</sup>,  
La Việt Hồng<sup>3</sup>, Lê Thị Ngọc Quỳnh<sup>4</sup>, Chu Đức Hà<sup>2</sup>, Lê Huy Hàm<sup>2</sup>

<sup>1</sup>Học viện Nông nghiệp Việt Nam, Hà Nội

<sup>2</sup>Trường Đại học Công nghệ, Đại học Quốc gia Hà Nội, Hà Nội

<sup>3</sup>Trường Đại học Sư phạm Hà Nội 2, Phú Thọ

<sup>4</sup>Trường Đại học Thủy lợi, Hà Nội

### Tóm tắt

Đậu tương (*Glycine max* L.) là cây trồng nhạy cảm với điều kiện nhiệt độ thấp, đặc biệt trong giai đoạn nảy mầm và sinh trưởng sinh dưỡng sớm, dẫn đến tỷ lệ mọc thấp, sinh trưởng kém và giảm năng suất. Nghiên cứu này được thực hiện nhằm đánh giá khả năng của xử lý từ trường tĩnh (MF) trong việc nâng cao khả năng chịu lạnh của giống đậu tương DT84 tại Việt Nam. Hạt giống được xử lý MF trước gieo trồng và được đánh giá dưới điều kiện nhiệt độ tối ưu và nhiệt độ thấp. Kết quả cho thấy xử lý MF giúp cải thiện động thái nảy mầm, giảm tỷ lệ cây dị thường và nâng cao sức sống cây con trong điều kiện lạnh. Trong giai đoạn sinh trưởng sinh dưỡng, cây xử lý MF có tỷ lệ mọc cao hơn, thân mầm dài hơn, diện tích lá lớn hơn, chiều cao cây và khối lượng sinh khối cao hơn, hệ rễ phát triển mạnh hơn, cũng như hàm lượng diệp lục cao hơn so với đối chứng không xử lý. Mặc dù xử lý MF chưa thể phục hồi hoàn toàn mức sinh trưởng như ở điều kiện tối ưu, nhưng đã giúp giảm đáng kể tác động ức chế của lạnh và thu hẹp khoảng cách sinh trưởng giữa hai điều kiện. Kết quả nghiên cứu khẳng định xử lý MF là biện pháp đơn giản, chi phí thấp và thân thiện môi trường, có tiềm năng ứng dụng trong thực tiễn nhằm nâng cao khả năng chống chịu lạnh và hiệu quả thiết lập quần thể đậu tương trong gieo trồng sớm.

**Từ khóa:** Đậu tương, điều kiện lạnh, từ trường, nảy mầm và sinh trưởng.