

Influence of Magnetized Seeds on Element and Microelement Intake of Green Gram (*Vigna radiata* L.)

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ABSTRACT

Building on the encouraging results from the initial cultivation of green gram under magnetic field treatments of varying intensities and exposure times, treatment T7 (225 mT for 75 minutes) proved to be the most effective. This treatment outperformed others in enhancing physiological traits such as germination rate, leaf area, shoot and root span, and plant height, accompanying improving chemical, biochemical, and yield-related parameters, including N, P, K, Fe, Mn, Zn, Cu content, chlorophyll a and b, carotenoids, acidity, vitamin C, and seed yield per plant. Further evaluation was conducted to assess how magnetic field exposure influenced the element intake of the plants. The absorption of key elements (N, P, K) and microelements (Fe, Mn, Zn, Cu) was quantified utilizing standard calculation methods. Statistical analysis confirmed that the combination of 225 mT magnetic field strength with a 75-minute exposure (T7) achieved the highest overall performance in the study.

Keywords: Magnetic field, Element intake, Microelement intake.

Highlights

- In addition to untreated seeds, mung bean seeds were subjected to MF treatments at different intensities and exposure durations.
- The results were assessed through various analytical methods, and element intake was quantified using standard calculation formulas.
- Data analysis was performed using ANOVA, as outlined in the study.
- Findings revealed that MF application during the initial cropping cycle promoted the growth, development, and production of green gram.
- Moreover, from the optimal treatment identified in the first cropping cycle, magnetic field exposure also improved the element and microelement absorption capacity of the plants.

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INTRODUCTION

Green gram (*Vigna radiata* L.), commonly known as mung bean, remains a key pulse crop in India due to its nutritional value, adaptability, and role in sustainable farming. In the 2023-24 agricultural year, green gram was cultivated over approximately 3.787 million hectares, yielding about 2.916 million tonnes with an average productivity of around 670 kg per hectare.

Cultivation during the Kharif season formed the bulk of this area around 31.94 lakh hectares, with states such as Rajasthan (\approx 69.3% of Kharif area), Karnataka (\approx 6.4%) and Maharashtra (\approx 5.7%) being the major contributors. In the Rabi season, the planted area dropped to about 5.93 lakh hectares, with Odisha accounting for around 82.4%, Andhra Pradesh 8.1% and Tamil Nadu 4% of Rabi green gram cultivation. This represents a slight decline in area and production compared with previous years, though productivity has improved, which helped moderate the impact of area contraction. Major producing states in 2023-24 include Rajasthan, Maharashtra, Karnataka, Odisha, Madhya Pradesh, Gujarat, and others.

Abiotic strains are among the most critical constraints to global food security as they severely limit plant growth, metabolic efficiency, and crop outputs. Such stresses, which include salinity, drought, heat, and extreme temperatures, are responsible for substantial agricultural losses, with their impact intensifying under the ongoing challenges of climate

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variability and land degradation (Nair *et al.*, 2019). Over the past few decades, declining crop productivity due to adverse environmental conditions has been consistently reported across major Agroecosystems, underscoring the urgent need for adaptive and resilient crop improvement strategies. Among these strains, salinity has emerged as one of the most detrimental factors, particularly in arid and semi-arid regions where irrigation practices and soil degradation exacerbate salt accumulation (Pratap *et al.*, 2019). High salinity disrupts water intake by creating an osmotic imbalance, while excessive sodium and chloride ions interfere with nutrient absorption and enzyme activity, leading to ion toxicity. In leguminous crops, salinity stress is especially damaging because it impairs nodulation and

symbiotic nitrogen fixation, processes that are central to soil fertility and sustainable production. Furthermore, elevated salt concentrations cause structural damage to chloroplasts and leaf mesophyll tissues, thereby reducing chlorophyll content and photosynthetic efficiency, which directly translates into yield losses (Hossain and Fujita, 2010). Consequently, understanding the physiological, biochemical and molecular responses of plants to salinity is essential for developing tolerant cultivars and designing management practices that can mitigate its adverse effects on agricultural productivity.

Adequate water supply, efficient uptake by roots and high-quality seeds are essential prerequisites for ensuring vigorous plant growth and sustainable agricultural productivity. This requirement has become increasingly critical in the face of rising global food demand coupled with diminishing freshwater resources, which pose significant challenges to modern farming systems (Abobatta, 2019). To address these challenges, researchers have been exploring non-conventional and eco-friendly approaches that can enhance crop performance without exerting additional pressure on natural resources. One such innovative approach involves the application of magnetic field treatments to seeds and irrigation water. Magnetic fields are known to interact with the intrinsic electrical properties of living organisms due to their resonant characteristics. Since plants, like other biological systems, contain electrostatic charges arising from ions, polar molecules and free radicals, they can act as natural bio-magnets that actively participate in various biochemical and physiological processes (Martinez *et al.*, 2017). When exposed to external magnetic fields, these charged particles can undergo altered mobility and alignment, potentially enhancing ion intake, enzymatic activity and membrane permeability. Such modifications can lead to improved water absorption, better nutrient assimilation and overall enhancement of seed vigor and crop quality. Consequently, magnetic seed and water treatments are increasingly being investigated as promising pre-sowing and crop management strategies to improve germination rates, stress resilience, and nutritional content, thereby offering a sustainable pathway to address the dual challenge of food security and resource conservation.

Sunita *et al.* (2015) demonstrated that exposing soybean and corn seeds to direct current MFs at early developmental stages significantly enhanced seed performance compared to untreated controls. The treatment resulted in notable improvements in several sprouting-related parameters, including sprouting rate, water intake efficiency, seedling length, wet and dry biomass accumulation and an overall increase in the vigor index, suggesting that MF exposure can positively modulate early physiological processes. A critical factor underlying these improvements is the accelerated establishment of a well-developed root system, which serves as the foundation for seedling establishment and subsequent crop growth. The development of an elongated primary root is particularly advantageous as it increases the effective surface area available for nutrient and water absorption from the soil, thereby facilitating better metabolic functioning and stress resilience in later stages of plant development (Azcon-Bieto and Talon, 2000). The initiation of root elongation is tightly linked

with the sprouting phase, beginning immediately after radicle emergence. This stage signifies a shift from a dormant physical state to an active biological phase during which intense cell division and elongation occur, primarily driven by mitotic activity in the root apical meristem. Root expansion during this critical window not only determines the plant's ability to access essential resources but also establishes the structural and functional base that supports shoot development, photosynthetic activity, and overall plant vigor. Consequently, seed priming techniques such as MF exposure represent a promising biophysical strategy for improving sprouting efficiency, root system architecture and crop establishment under both optimal and stress-prone environments.

Muraji *et al.* (1998) reported that corn seedlings exposed to alternating current MFs at frequencies of 10 Hz and 20 Hz exhibited significant morphological changes in root development with root diameters approximately 20% greater than those of untreated controls. This finding indicates that MF exposure can stimulate cellular processes associated with root enlargement and possibly enhance the functionality of the root system. A broader root structure is particularly advantageous as it increases the overall root surface area, thereby improving the plant's efficiency in accessing soil resources. Root span and surface area are widely recognized as critical physiological traits for evaluating nutrient acquisition potential, water intake efficiency and overall plant vigor (Wang *et al.*, 2006). Enlargement of root diameter may be linked to enhanced cell division and elongation in the cortical and vascular tissues, processes that contribute not only to structural strength but also to increased capacity for nutrient and water transport. Moreover, a larger root surface facilitates greater interaction with the rhizosphere, promoting beneficial microbial associations such as symbiotic nitrogen fixation and mycorrhizal colonization, which further enhance nutrient availability. These morphological and physiological modifications in response to MF treatment highlight the potential of biophysical seed and plant conditioning strategies to improve early-stage crop establishment, stress resilience and long-term yield stability.

This research was designed to explore the intake properties of plants post-effect of MF applied upon the seeds of green gram.

MATERIALS AND METHODS

In the first cropping cycle, seeds of the Gujarat-4 variety of green gram (*Vigna radiata* L.) were procured from the Gujarat State Seeds Corporation Ltd., Gujarat, India. The field trial was conducted under natural sunlight at Navi Vasni, Aravali, Gujarat (23°14'52"N, 73°1'43"E). Before sowing, the seeds received no additional treatment apart from magnetic field exposure. Sowing was done directly into the field, resulting in a randomized block design (RBD) along with three duplicates for each therapy. Irrigation was provided as needed, and weeds were manually removed throughout the growth period.

Seed magnetization was carried out using a double-coil electromagnet system capable of generating a magnetic field ranging from 0 to 0.700 Tesla. The gap between the magnetic poles could be adjusted via rotating knobs located at the ends of the electromagnets (Fig. 1). Magnetic field intensity was

controlled by adjusting coil positioning and using a variable power supply, with measurements verified using a Gauss meter. During treatment, seed samples were placed in the gap between the two poles of the magnetic coil.

The seeds were divided into ten experimental groups, consisting of one untreated control and nine magnetic field-treated sets, labeled T₁ to T₁₀. Each group contained five seeds and was replicated three times. A complete description of all treatments is distributed in Table 1.

All cultivation procedures were carried out following standard agronomic practices recommended by the Ministry of Agriculture for green gram production.

The chemical traits of exploratory soil, as determined through laboratory analysis, are presented in Table 2.

After getting data on chemical analysis about concentrations of elements (N, P, K) and microelements (Fe, Mn, Zn, Cu), intake intensities were calculated using the following formulas:

Element intake by plant (kg ha⁻¹)

Element intake (N, P, K) by the green gram crop was resolved using methods suggested by Godebo *et al.* (2021). Major element intake (kg ha⁻¹) =

$$\frac{\text{Content in plant (\%)} \times \text{Dry mass yield} \left(\frac{\text{kg}}{\text{ha}}\right)}{100}$$

Microelement intake by plant (g ha⁻¹)

An absorption of Fe, Mn, Zn and Cu by green gram plants was assessed following the methodology described by Dhaliwal *et al.* (2022).

Intake of Microelement (g ha⁻¹) = $\frac{\text{Content in plant} \left(\frac{\text{mg}}{\text{kg}}\right) \times \text{Dry mass yield} \left(\frac{\text{kg}}{\text{ha}}\right)}{1000}$



Fig 1: Electromagnetic unit setup for seed magnetization

Table 1: Exploratory treatments

Treatments	Detail
T1	Control seeds
T2	Magnetize seeds at 200 mT for 25 minutes
T3	Magnetize seeds at 200 mT for 50 minutes
T4	Magnetize seeds at 200 mT for 75 minutes
T5	Magnetize seeds at 225 mT for 25 minutes
T6	Magnetize seeds at 225 mT for 50 minutes
T7	Magnetize seeds at 225 mT for 75 minutes
T8	Magnetize seeds at 250 mT for 25 minutes
T9	Magnetize seeds at 250 mT for 50 minutes
T10	Magnetize seeds at 250 mT for 75 minutes

Each treatment contains 3 replications.

Data on element and microelement intake were analysed using analysis of variance (ANOVA), and critical difference (CD) was intended at the 5% possibility level following the statistical process depicted by Panse and Sukhatme (1954).

RESULTS

Element Intake by the Green Gram Plant

Nitrogen intake

The influence of different magnetic field treatments on nitrogen intake is presented in Table 3. During the first cropping cycle, a clear and statistically significant variation in nitrogen absorption was observed among the treatments. Among all, treatment T₇ recorded the highest nitrogen intake, reaching 22.16 kg ha⁻¹, which was notably greater than that of the control group (T₁) at 11.91 kg ha⁻¹. This represents an increase of 60.15% over the untreated control during the same growth period. The superior performance of T₇ suggests that exposure to a magnetic field of 225 mT for 75 minutes was highly effective in enhancing nitrogen assimilation in green gram plants during early cultivation. In contrast, the lowest nitrogen intake was found in treatment T₁₀, which registered only 2.88 kg ha⁻¹, indicating that certain magnetic field conditions may have an inhibitory effect on nitrogen absorption. These discoveries identify a pivotal role of optimized magnetic field parameters in improving element intake efficiency in crop production.

Phosphorus intake

The impact of different MF treatments upon phosphorus intake is presented in Table 3. During the first cropping cycle, statistically significant differences in phosphorus absorption were noticed among treatments. Treatment T₇ emerged as the most effective, recording a phosphorus intake of 2.60 kg ha⁻¹, which was substantially higher than most other treatments. This intake level was comparable to that of treatment T₄, indicating that both treatment conditions had a positive influence on phosphorus assimilation. When compared with the control

Table 2: Chemical analysis of the exploratory soil

Components	Available values
pH	6.8
carbon (%)	0.2709
Nitrogen (kg ha ⁻¹)	154
Phosphorus (kg ha ⁻¹)	51
Potassium (kg ha ⁻¹)	281
Micronutrients	
Cu (mg kg ⁻¹)	0.68
Fe (mg kg ⁻¹)	7.46
Mn (mg kg ⁻¹)	8.4
Zn (mg kg ⁻¹)	1.12
soluble ions	
SO4- (mg kg ⁻¹)	11.3

(T₁), which recorded only 1.18 kg ha⁻¹, treatment T₇ achieved an increase of 75.13% in phosphorus intake during the same cycle. In contrast, the lowest intake was observed under treatment T₁₀, with a value of just 0.31 kg ha⁻¹, suggesting that certain magnetic field conditions may suppress phosphorus absorption. These findings indicate that an optimized magnetic field treatment, particularly the parameters applied in T₇, can significantly enhance phosphorus availability and intake in green gram during the early stages of growth.

Potassium intake

The power of various MF treatments on potassium intake is summarized in Table 3. In the first cropping cycle, potassium absorption showed statistically significant variation across the treatments. Among all tested conditions, treatment T₇ demonstrated the highest potassium intake, recording 9.03 kg ha⁻¹, which was markedly greater than that of any other treatment. Compared with the control (T₁), which registered only 2.29 kg ha⁻¹, T₇ achieved an impressive 119.08% increase in potassium intake. This substantial improvement highlights the positive effect of the magnetic field parameters used in T₇ on enhancing nutrient assimilation. In contrast, the lowest potassium intake during the cycle was observed under treatment T₁₀, with a value of 1.64 kg ha⁻¹, suggesting that certain magnetic field exposures may have a less favourable or even inhibitory influence on potassium absorption. Overall, the results indicate that optimized magnetic field application, as in T₇, can significantly boost potassium availability and utilization in green gram during early growth stages.

Microelement Intake by Green Gram Plant

Iron intake

Implications of different MF treatments upon iron intake during a first cropping cycle are presented in Table 4. Iron absorption was notably influenced by the applied treatments, with significant variation observed across the experimental groups. Among all treatments, T₉ recorded the highest iron intake, reaching 1655.39 g ha⁻¹, which was substantially greater than that of any other treatment in the cycle. When compared to the control (T₁), which registered 653.57 g ha⁻¹, treatment T₉ achieved an impressive increase of 86.77% in iron intake. This result highlights the strong positive effect of the magnetic field parameters used in T₉ on enhancing micronutrient assimilation. Conversely, the least iron intake was detected in T₁₀, with a value of just 287.85 g ha⁻¹, suggesting that certain magnetic field conditions may inhibit iron absorption.

Manganese intake

Consequences of different MF treatments upon manganese intake during the first cropping cycle are presented in Table 4. Manganese absorption showed significant variation among the treatments, indicating that magnetic field exposure influenced micronutrient assimilation in green gram. Among the tested conditions, treatment T₉ recorded the highest manganese intake at 280.10 g ha⁻¹, closely followed by treatment T₄, with no statistically significant difference between the two. Compared with the control (T₁), which registered 196.74 g ha⁻¹, T₉ achieved a 34.96% increase in manganese intake during the same cycle.

This improvement suggests that the magnetic field parameters applied in T₉ positively affected manganese availability and absorption. In contrast, the lowest intake was observed under treatment T₁₀, which recorded only 49.17 g ha⁻¹, highlighting the possibility that certain magnetic field conditions may limit manganese assimilation.

Zinc intake

The outcome of different MF treatments upon zinc intake during the first cropping cycle is presented in Table 4. Zinc absorption varied considerably among the treatments, indicating that magnetic field application had a strong effect on this micronutrient's assimilation in green gram. Among the treatments, T₉ recorded the highest zinc intake at 37.91 g ha⁻¹, which was significantly greater than most other treatments and closely comparable to T₇. When compared to the control (T₁), which recorded 23.55 g ha⁻¹, T₉ demonstrated a 46.72% improvement in zinc intake. This enhancement suggests that the magnetic field conditions used in T₉ were particularly effective in increasing zinc availability and absorption. In contrast, very little zinc intake was noted in treatment T₁₀, which registered only 10.28 g ha⁻¹, suggesting that certain magnetic field parameters may reduce micronutrient assimilation. These results underline the potential of optimized magnetic field exposure to boost zinc uptake efficiency in green gram during the early stages of crop growth.

Copper intake

Impact of various MF treatments upon copper intake during a first cropping cycle is shown in Table 4. Copper absorption was noticeably influenced by the applied treatments, with measurable differences observed across the experimental groups. Among all treatments, T₇ recorded the highest copper intake, reaching 33.58 g ha⁻¹, which was slightly higher than the values obtained for T₁ and T₄, both of which were statistically comparable to T₇. Compared with the control (T₁),

Table 3: Element intake by the plant of green gram

Treatment	Nitrogen intake (kg ha ⁻¹)	Phosphorus intake (kg ha ⁻¹)	Potassium intake (kg ha ⁻¹)
T ₁	11.91	1.18	2.29
T ₂	12.81	1.49	2.10
T ₃	10.31	1.29	2.47
T ₄	17.54	2.53 ^a	4.59
T ₅	14.06	1.79	5.05
T ₆	12.64	1.90	4.99
T ₇	22.16 ^a	2.60 ^a	9.03 ^a
T ₈	9.63	1.45	3.37
T ₉	14.96	1.62	6.97
T ₁₀	2.88	0.31	1.64
SED (±)	1.038	0.143	0.366
CD (5%)	2.182	0.300	0.769

Values are means of 3 replications

which recorded 29.61 g ha⁻¹, treatment T₇ showed a 12.56% improvement in copper intake during the same cropping cycle. This moderate but consistent increase indicates that the magnetic field parameters applied in T₇ had a positive effect on enhancing copper assimilation in green gram. In contrast, the lowest copper intake was observed under treatment T₁₀, which registered only 5.84 g ha⁻¹, suggesting that certain magnetic field conditions may limit copper absorption. These findings highlight that while the response of copper intake to MF exposure may be less pronounced than for other nutrients, optimal treatment settings can still yield measurable improvements.

DISCUSSION

Extensive experimental evidence across a wide range of crop species suggests that MF treatments can induce multiple agronomic benefits, making them an emerging tool in sustainable agricultural practices. Reported advantages include improvements in seed quality, enhancement of vegetative and reproductive growth traits and more efficient nutrient assimilation mechanisms. In leguminous crops such as green gram (*Vigna radiata*), seed priming with carefully calibrated magnetic field intensities and exposure durations has been shown to markedly accelerate sprouting, resulting in faster and more uniform seedling emergence. Early establishment of vigorous seedlings provides a competitive advantage under both optimal and stress conditions, ensuring better crop stand and resilience throughout the growth cycle. Furthermore, MF exposure influences the transport and intake of essential elements, particularly nitrogen, phosphorus, and potassium, which are fundamental for protein synthesis, energy metabolism and osmotic balance. At the same time, increased absorption of microelements such as iron, manganese, zinc and copper supports enzymatic activities, chlorophyll biosynthesis and antioxidant defence systems, thereby strengthening overall physiological performance. Such nutrient-related improvements contribute not only to enhanced biomass accumulation but also to reproductive efficiency, ultimately reflected in higher seed yield and quality. Collectively, these findings highlight magnetic field technology as a cost-effective, non-invasive and environmentally sustainable approach for crop enhancement, with the potential to complement conventional agronomic practices and reduce dependence on chemical inputs.

Mahajan and Pandey (2014) conducted a comprehensive study on sprouting-related parameters, including average sprouting rate, water intake efficiency and magnetic responsiveness of seeds, and demonstrated that exposure to static magnetic fields (SMFs) significantly promoted sprouting in green gram (*Vigna radiata*), even when seeds were subjected to off-season conditions. Their results provide evidence that magnetic treatments exert a direct influence on the dynamics of water absorption during the initial physical phase of sprouting, a stage that is critical for reactivating metabolic activity in dry seeds. Enhanced hydration of embryonic tissues under MF exposure facilitates quicker restoration of enzyme activity, mobilization of stored food reserves, and initiation of key biochemical pathways that drive sprouting. One of the central physiological outcomes observed was the improvement in turgor pressure within the radicle cells of seedlings derived

from magnetically treated seeds. Elevated cellular turgidity not only accelerates radicle elongation but also provides the mechanical force required for successful emergence through the seed coat and soil surface. This stronger and more vigorous early root growth establishes a robust foundation for subsequent seedling development, ensuring better resource acquisition and improved crop establishment. The findings suggest that magnetic seed treatment represents a promising biophysical priming method capable of enhancing sprouting efficiency and vigor, thereby supporting higher crop productivity, particularly in environments where seasonal or climatic constraints often limit conventional seed performance.

The results revealed a substantial increase in element and microelement intake in response to treatment T₇. As noted by Wang *et al.*, (2006), the absorption of essential nutrients acts as a key physiological sign of plant growth and overall condition. In the first cropping cycle, plants subjected to magnetic field exposure under T₇ conditions showed significantly greater intake of major elements such as nitrogen, phosphorus, and potassium, as well as important microelements including iron, manganese, zinc, and copper, compared to both the control group (T₁) and other magnetic treatments. This superior nutrient absorption was accompanied by improved root development in T₇ treated plants, suggesting that the enhanced root characteristics contributed to their higher nutrient acquisition and better overall growth performance during the initial cropping season.

The observed improvements in plant growth and biomass accumulation following magnetic seed treatment appear to be associated with multiple interrelated physiological and biochemical processes. One major contributing factor is the enhancement of light interception, which improves canopy architecture and enables more effective utilization of incident radiation for photosynthetic activity. Alongside this, plants derived from magnetically treated seeds have been reported to exhibit reduced levels of oxidative reductase (OR), suggesting a strengthened antioxidant defense system that mitigates oxidative stress and prevents damage to cellular structures such as membranes, proteins, and chloroplasts. The reduction in oxidative burden ensures greater stability of photosynthetic pigments and enzymes, thereby supporting sustained photosynthetic efficiency.

Moreover, MF exposure has been linked to improved intake and translocation of essential elements, which further contribute to chlorophyll biosynthesis, electron transport efficiency and enzymatic activity in carbon assimilation pathways. Collectively, these changes promote higher rates of photosynthesis and enhanced carbon fixation. The surplus assimilated carbon is then redistributed toward various sink organs, with a significant proportion allocated to reproductive structures such as flowers and pods. This preferential allocation not only ensures better pod filling and seed development but also translates into measurable increases in final yield. In the case of green gram (*Vigna radiata*) the combined effects of improved light capture, reduced oxidative stress, enhanced nutrient absorption and greater photosynthetic efficiency underscore the potential of MF treatments as a sustainable agronomic intervention for boosting productivity under both optimal and stress-prone conditions.

Table 4: Microelement intake by plant of green gram

Treatment	Iron intake ($g\ ha^{-1}$)	Manganese intake ($g\ ha^{-1}$)	Zinc intake ($g\ ha^{-1}$)	Copper intake ($g\ ha^{-1}$)
T ₁	653.57	196.74	23.55	29.61 ^a
T ₂	1152.03	197.01	18.33	12.08
T ₃	1358.65	221.64	28.96	20.69
T ₄	1340.89	265.19 ^a	26.85	26.87 ^a
T ₅	1170.09	132.15	16.32	19.06
T ₆	1120.78	177.75	19.56	21.36
T ₇	1414.11	162.75	35.81 ^a	33.58 ^a
T ₈	1054.17	173.19	29.48	17.27
T ₉	1655.39 ^a	280.10 ^a	37.91 ^a	21.52
T ₁₀	287.85	49.17	10.28	5.84
SED (\pm)	75.019	14.844	2.794	2.833
CD (5%)	157.615	31.188	5.870	5.952

Values are means of 3 replications

The marked improvement in vegetative growth observed in treatment T₇ reflected in increased leaf area, shoot length, root length, and plant height, can be largely attributed to a rise in absorption of key chloroplast pigments, namely chlorophyll a, chlorophyll b, and carotenoids. Elevated pigment levels enhance the plant's photosynthetic capacity, thereby increasing the production of assimilates available for supporting vegetative development. This boost in assimilate availability translated into notable growth advantages for the treated plants. Previous studies have indicated that magnetic field exposure can alter the transport properties of cellular plasma membranes, which are essential for regulating the uptake and assimilation of nutrients critical for cellular metabolism and growth (Azharonok *et al.*, 2009). Such physiological changes may ultimately contribute to the higher yields recorded in magnetically treated plants.

Exposure to external magnetic fields has been associated with improved seed vigor through their influence on various biochemical processes, including the activation and regulation of proteins and enzymes. Such effects can enhance metabolic activity during germination and early seedling growth. Several studies have reported that magnetic field treatment promotes increased ion uptake, which in turn improves the nutritional composition of the plant (Martinez *et al.*, 2017). This enhanced nutrient acquisition supports stronger physiological development and may contribute to improved crop performance.

CONCLUSION

The discovery of this work indicates that an application of MF treatment to seeds during the first cropping cycle can significantly improve the nutrient intake capacity of green gram plants. In particular, treatment T₇ (225 mT for 75 minutes), identified as the optimal condition based on its superior performance across most measured parameters, consistently outperformed the control (T₁) as well as all other magnetic treatments. T₇ showed marked improvements in the

absorption of both elements and microelements, indicating its strong positive influence on plant nutrient assimilation. This enhancement in intake efficiency suggests that MF exposure during the initial cropping cycle can play a crucial role in optimizing plant nutrition, thereby supporting better growth, development, and potential yield outcomes.

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AUTHOR CONTRIBUTION

Corresponding author and co-authors play a role in the visualization and execution of this experiment. The manuscript was prepared by the corresponding author and verified by co-authors. Correction was made at each stage where needed and the final manuscript was prepared with the consent of all three authors mentioned above.

CONFLICT OF INTEREST

The authors state that they have no conflicts of interest related to their work.

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