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ENHANCING SEED QUALITY BY MAGNETIC SEED TREATMENT: REVIEW

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ABSTRACT

Seed quality is an important factor for crop production. It ensures high yield, enhanced plant health, and efficient resource utilization. One of the promising seed quality enhancement techniques is magnetic seed treatment. This technique involves exposing the seeds to magnetic field. It improves physical, genetic, and biochemical qualities of seeds and enhances seed performance, particularly during the critical period from sowing to seedling establishment, when the seed is vulnerable to stresses such as pathogens, insects, water, light, and temperature fluctuations. Magnetically treated seeds exhibited better germination rates, increased seedling height, and greater fresh and dry weights than untreated seeds. This treatment helps seeds to absorb water more efficiently and activates important enzymes, such as α-amylase, which helps to break down stored nutrients in the seed, providing energy for the growing plant. Additionally, it promotes the production of nitric oxide, a compound that helps plants handle stress, and can alter the expression of genes associated with seed germination and stress tolerance.

Keywords: Magnetic seed treatment, seed quality enhancement

1. INTRODUCTION

The Earth's geomagnetic field (GMF) is an inevitable environmental factor for all living organisms. It affects plants naturally, and by modifying magnetic fields, seed quality and yield can be enhanced. Magnetic field technology has become popular as it is an eco-friendly technique that does not produce waste or emit harmful radiation, nor does it require an external power source. It can be used in sustainable agriculture as it is low-cost, reusable and harmless method for crop productivity enhancement (1).

2. MAGNETIC SEED TREATMENT

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Magnetic seed treatment is an innovative approach for enhancing seed quality. The seeds were exposed to a magnetic field (static or pulsed) of low to medium intensity before planting. This technique gained its significance in the early 20th century (2). Initial studies showed that magnetic fields significantly influence the dynamics of seed germination and enhance vigour and plant growth by increasing enzyme activity and nutrient uptake, which in turn results in increased crop yields. Sunflower seeds exposed to a magnetic field of 100 mT for 10 min showed significantly increased germination rates and crop growth when compared to untreated seeds (3).

Magnetic seed treatment is an alternative method to traditional pre-sowing techniques as it is non-destructive, improves agricultural productivity, and addresses challenges such as dormancy and seed deterioration during storage.

Alterations in the physical and chemical properties of water are the mechanism underlying magnetic seed treatment, which increases ion mobility and metabolic pathways in seeds. The magnetic field modifies the electronic structure of water, which leads to changes in viscosity and dielectric properties that increase nutrient absorption by seeds. The treatment also increases growth hormones, such as indole-3-acetic acid (IAA) and gibberellic acid (GA3), which help in shoot and root development. These biochemical changes, in turn, increase plant growth dynamics and yield, making magnetic seed treatment a better alternative to traditional seed priming methods (4).

3. METHODS OF MAGNETIC SEED TREATMENT

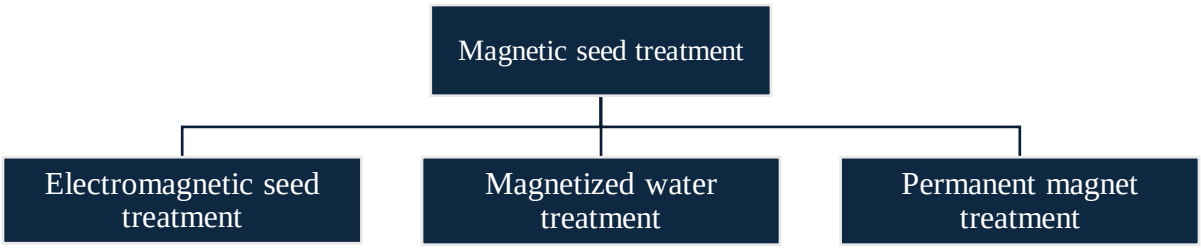

Figure 1: Methods of magnetic seed treatment

3.1 Electromagnetic seed treatment

The electromagnetic seed treatment is performed using an electromagnetic field generator, which produces a magnetic field of varying intensities and durations. The electromagnetic field generator includes a wire coil that carries electric current. As current flows, a magnetic field is generated around the coil. The seeds are then positioned within this field, where they experience the effects of magnetic forces.

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When exposed to a magnetic field, soybean seeds showed a significant increase in growth and yield compared to normal seeds. In this study, the seeds were placed between the poles of an electromagnet, where they were exposed to a static magnetic field. The container containing the seeds was positioned in this field. A digital gauss meter was used to monitor the magnetic field strength. Seeds were exposed to magnetic fields of 150 mT for 1 h and 200 mT for 1 h. This study revealed that both levels of magnetic treatment led to improvements in plant height, leaf area, and dry weight. However, seeds exposed to a stronger field of 200 mT showed better results than those treated with 150 mT (5).

3.2 Magnetized water treatment

Magnetized water is created by exposing water to a magnetic field, which alters its physical properties (6). This can be achieved in different ways, such as by-passing water through a magnetic device or placing it within a field generated by permanent magnets or electromagnets. Magnetized water treatment can be performed by soaking the seeds in magnetized water or irrigating the normal seeds with magnetized water.

Seeds soaked in magnetized water showed improved germination and enhanced plant growth. In this study, magnets were fixed on both sides of the wooden bars to create a magnetic field through which water flowed. Two sets of 13 magnets were mounted on opposite sides of the bars, with a PVC pipe running through the magnetic field, which had an intensity of 211 mT. The strength of the magnetic field was measured along the length of the pipe to ensure consistency (3).

In a study conducted in cowpea, the magnetized water is created using a rectangular water treatment device with 12 pairs of neodymium magnets and a round-bar water treatment chamber consisting of six pairs of magnets. Water was allowed to pass through this chamber, and the magnetic flux densities were measured using a Gauss meter. Magnetized water was used to irrigate the cowpea plants. The results showed that plants irrigated with magnetized water produced better yield, germination rate, and growth characteristics than plants irrigated with non-magnetized water (7).

3.3 Permanent magnet treatment

Seeds are subjected to magnetic treatment using permanent magnets, which provide a static magnetic field without an external power source.

Magnetic field is setup using permanent magnets. The desired magnetic field intensity can be achieved by coupling the magnets. Seeds were placed inside the germitest paper strip, which contained compartments to hold each seed. This paper acts as an envelope that can be placed inside the central hole of a permanent magnet. Seeds were placed with the embryo facing the south pole of the magnet because magnetic fields influence moving electric charges, such as ions. Positioning

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the embryo toward the south pole helps those ions on track as they move toward the embryonic region, preventing any unwanted deviation (8).

4. EFFECTS OF MAGNETIC SEED TREATMENT

Based on the results of multiple scientific investigations, magnetic seed treatment improves crop germination and yield. Marigold seeds and cereals (rice, wheat, maize, and barley) benefit from magnetic field exposure because they accelerate germination, strengthen seedlings, and alter biochemical measurements, as reported in the literature (9). Examination of magnetic seed application on crops outside southern Alberta indicated higher yields for barley and wheat seeds, but the results for oats remained unchanged (10). The effectiveness of seed treatment remains unaffected by the treatment timing, magnetic field strength, and equipment used in the process (10).

Further examination of the biochemical mechanism responsible for these changes was performed in another study and found that the application of magnetic seed treatment increased amylolytic activity in the dormancy and germinating of barley and wheat seeds. The results of this study showed that magnetic treatments resulted in higher enzymatic activities for seed germination as well as the growth of these plants (11).

A quantitative approach to study the growth of two barley cultivars from magnetically treated seeds and compared them with those from untreated seeds was conducted (12). This study supports the initial belief that magnetic treatments cause substantial growth advantages. Another study included other crops, showing that the mentioned type of treatment had a proliferative effect on the germination and yield outputs of plants, such as flax, buckwheat, sunflower, and field pea in the pre-seeding stage (13). In addition, a study showed that maize seeds exposed to static magnetic fields could experience an improvement in germination and vigor (14).

Research demonstrates that agriculture reacts favorably to magnetic water treatment through enhanced water-use efficiency, together with better nutrient accessibility (15). The promising technological approach needs standardized treatment procedures to resolve methodological inconsistencies that appear between studies.

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Table 1: Overview of magnetic seed treatments across different crops

Crop	Treatment types	Field strength	Exposure duration	Crop responses	References
Coffee	Permanent magnet treatment	10 mT 28 mT	6 days	Improved germination rates, seed viability, faster Germination Speed Index (GSI), increased Emergence Speed Index (ESI), enhanced membrane permeability, higher radicular protrusion levels	(8)
Sunflower	Electromagnetic seed treatment	100 mT 150 mT	10 min	High root and shoot length, root shoot ratio, increased α-amylase activity, total soluble sugars and reducing sugars	(3)
Sunflower	Electromagnetic seed treatment	50 mT 80 mT 100 mT	45 min 30 min 15 min	Increased percentage of mean germination time High phenolic content High flavonoid content	(16)
Tomato	Magnetized water treatment	3.5-136 mT	-	Higher germination percentage, increase seedling length, dry weight, fruit number, fruit yield in salinity conditions	(17)
Tomato	Permanent magnet treatment	3.5-136 mT	20 min	Increased germination percentage, dry weight, seedling length in salinity conditions	(17)
Okra	Electromagnetic seed treatment	100 mT	20 min	High seedling emergence, fresh weight, dry weight, fruits per plant, fruit yield per plant, photosynthetic rate, transpiration rate, short mean emergence time	(18)

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Sunflower	Electromagnetic seed treatment	0.2 T & 0.3 T	20 min	Improve chlorophyll content in water stressed condition	(19)
Soybean	Electromagnetic seed treatment	200 mT	1 h	Increased growth parameters, increased biomass, yield	(5)
Lentil & Durum wheat	Magnetized water treatment	12,900 and 13,200 Gauss	-	Higher root and epicotyl length	(20)

5. BENEFITS OF MAGNETIC SEED TREATMENT

5.1 Water uptake enhancement

Magnetic seed treatment enhances the seed's water absorption capacity which is essential for germination (21). This is achieved by changing the physical properties of the water. The magnetic field can influence the structure and behaviour of water molecules, allowing water to penetrate the seed coat more easily and enter the internal tissues of the seed. This alteration promotes hydration and facilitates the intake of moisture by the seeds (4).

5.2 Activation of enzymatic activity

Magnetic seed treatment initiates the activation of major enzymes involved in seed metabolism, such as α-amylase. This enzyme is essential for the conversion of stored carbohydrates to sugars, which are used to provide energy for seed development. By accelerating metabolic activity, magnetic seed treatment releases the energy required for germination and seedling development (3).

5.3 Nitric oxide production

Magnetic seed treatment promotes the synthesis of nitric oxide, a critical signalling molecule that helps to regulate plant responses to environmental stress and supports germination. The study indicated that higher Nitric oxide levels significantly improve seedling vigour and resilience to adverse conditions (22). Nitric oxide helps in enhancing water permeability, promotes growth, relaxation of seed coats by modulating stress response.

5.4 Gene expression modulation

Magnetic field exposure can affect the expression of genes related to germination and stress tolerance. Magnetic seed treatment tends to upregulate antioxidant defences, growth regulation, and

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stress resistance genes. This gene modulation increases the capacity of the seed to withstand environmental stresses, such as oxidative stress, and enhances longevity and vigour. By reinforcing these internal defence and growth mechanisms, magnetically treated seeds are more likely to survive under various conditions (22).

5.5 Physiological improvements

Seeds exposed to magnetic fields generally exhibit higher germination percentages, higher seedling heights, and higher biomass than untreated seeds. These enhancements were attributed to improved physiological characteristics, such as root and shoot growth. Strong roots stabilize plants and allow for nutrient and water uptake, whereas healthy shoots enable photosynthesis and plant structure. Together, these advantages lead to healthier and more robust plants, resulting in improved establishment and increased crop production (23).

6. FACTORS AFFECTING MAGNETIC SEED TREATMENT

6.1 Magnetic field strength

Different plants thrive under specific magnetic field strengths, with moderate levels proving to be best in boosting seed metabolism and growth. These optimal magnetic intensities help activate enzyme activity, enhance nutrient and water absorption, and improve germination (3). By selecting the appropriate magnetic field strength for each plant species, growers can maximize the benefits of magnetic seed treatment.

6.2 Exposure time

The amount of time seeds was treated in the magnetic field played an important role in determining the effectiveness of the treatment. If the exposure is short, the seeds may not obtain enough energy to undergo metabolic changes. On the other hand, leaving seeds too long can also cause stress. In tomato, exposure time of 10-15 minutes at 12.5 mT significantly improved germination rates and enhanced growth, whereas 5 minute exposure time showed negligible effect (24). In barley, seeds treated for 6 h daily for 5 days at 7 mT showed increased seedling biomass, delayed flowering, and reduced harvest index (25). To obtain maximum benefits, a correct balance in the exposure time is important.

6.3 Seed orientation

The orientation of seeds plays a crucial role in energy absorption. When the seeds were aligned parallel to the field lines, they absorbed energy more efficiently, leading to better results. In contrast, seeds placed perpendicular to the field may consume less energy, which results in a weaker response compared to former (26). Ensuring the correct orientation during magnetic treatment can help to maximize its benefits.

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6.4 Seed types and condition

Plants respond differently to magnetic treatments, with some species benefiting significantly, whereas others show little to no improvement. Some plants may experience higher germination rates and better overall growth when exposed to magnetic fields, whereas others may not react as strongly. These differences highlight the importance of considering the unique genetic and physiological traits of each plant to customize magnetic treatments for the best agricultural results. Seeds that are low in vigour or stored under suboptimal conditions often benefit more from such treatments, as they help to revitalize their growth potential (27).

7. LIMITATIONS OF MAGNETIC SEED TREATMENT

Exact control over exposure time and strength is necessary for magnetic field (MF) treatments. Weaker or excessive exposure results in decreased efficacy or negative outcomes, and beneficial effects are frequently observed within specific ranges. For instance, research on barley revealed that while magnetic treatment could speed up maturation, it would lower yields under drought conditions because the soil would not be sufficiently moist during crucial growth stages (10).

Different plant species react differently to magnetic fields. According to research, the ideal parameters vary depending on the crop; therefore, customized methods are required instead of a general application (19). Large-scale agricultural adoption without previous species-specific testing is difficult because of this variability.

Environmental factors affect the effectiveness of magnetic treatments. Compared with controls, treated seeds in barley trials produced denser plant populations that had a harder time with drought, which led to lower test weights and yields (10).

8. FUTURE PROSPECTS

Future research should focus on optimization of magnetic seed treatment parameters, i.e., to find the best combinations of magnetic field strength and exposure time for various crop species, so that the maximum germination and growth responses can be attained. Further research should also investigate integrating these treatments with other agronomic practices, for example, organic fertilizers and integrated pest management, to potentially enhance their combined effectiveness.

Practical issues should be addressed for magnetic seed treatments to find widespread agricultural acceptance. Issues on the cost-effectiveness, scalability, and farmer education on the benefits and best methods of magnetic seed treatment have to be looked at. Addressing these aspects would open up the pathway for the integration of magnetic seed treatments into traditional farming systems for increased crop yields and sustainability.

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9. CONCLUSION

Magnetic seed treatment is a game-changer in agriculture, as it reduces the use of chemical fertilizers, thus reducing environmental damage. This innovative technique improves seed germination, growth, and yield, thereby enhancing agricultural productivity. This method uses a magnetic field to treat the seeds, which results in higher germination rates and improved seedling growth, vigour indices, dry weight, and fresh weight of seedlings, as evidenced by studies showing enhanced performance in crops such as soybean (28). Magnetic treatment enhances the seed's resilience to abiotic stresses such as drought and salinity, which in turn reduces susceptibility to diseases owing to their overall improved health (17). Overall, magnetic seed treatment is an eco-friendly approach for agriculture.

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