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Germination of Rice Seeds as affected by Magnetic Field and Carry Over Seed Lots

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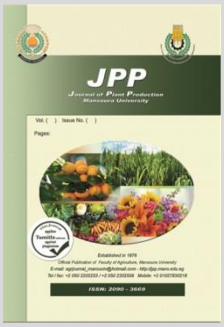

ABSTRACT

Rice seed germination and seedling establishment of the vigorous seedling is an important juncture life cycle in plant, and it decides the success of crop cultivation. Static or pulse magnetic field exposure rice seed lots is known to change and stimulate the biological, and biochemical utilization. The current work aimed to enhance the rice seed germination, seedling establishment as affected by carry over seed and static or pulse magnetic field at initial germination, in addition the physiological mechanism of seed age, seedling vigor and competitiveness. The field experiment was conducted with two rice seed lots viz., fresh and old seed and five magnetic field treatments viz., **T1:** Control, **T2:** 50 (Millitesla) mT static 2 hours, **T3:** 50 mT 5 min 2 hours pulse, **T4:** 100 mT 2 hours static, and **T5:** 100 mT 5min 2 hours pulse. Results indicated that all measured parameters were over nonexposed. Highly significant differences among magnetic field treatments which exposure seeds to 50 mT for two hours performed better germination percentage and seedling length whereas, minimum was noticed under control. In respect of seed quality parameters, significantly higher seed germination, shoot length, root length seedling length, seedling dry weight, seedling vigour index 1, seedling vigour index 2, field emergence and proline content were recorded in the 50 mT for 2 hours in static and pulse. A highly significant correlation was obtained between vigour tests and field emergence. Magnetic field could be a promising technique to improve rice establishment and productivity with fresh and aged seeds.

Keywords: Rice, magnetic field, seed lots, seed germination, seedling vigor.

INTRODUCTION

Rice (*Oryza sativa* L.) stands as the most crucial staple food crop globally, feeding over half of the world's population (Mohapatra et al., 2022). While the human population continues to grow annually, the amount of land available for cultivation remains constant. Therefore, to meet the increasing food demands of a growing population within these limited agricultural areas, rapid growth in crop production is essential. Modern agricultural efforts are now in search of an efficient eco-friendly production technology based on physical treatment of seeds to increase the seedling vigor and crop establishment. In sustainable farming methods, seed treatments are essential for enhancing plant health, reducing disease pressure, and increasing crop yields (Yadav et al., 2025). Observations suggest that plants derived from seeds treated with a magnetic field demonstrate superior field performance, manifesting as increased field emergence, vigorous growth, and improved seed yield and quality. Magnetic treatment can be static or pulse magnetic stimulation. The earliest research, conducted by (Savostin, 1964) showed that rice seedlings elongated more quickly under magnetic influence. Later (Murphy, 1942) showed changes in seed germination due to a magnetic field. According to (Aladjadjiyan, 2002) findings, the magnetic field enhanced the shoot development of maize. This enhancement was evident in the boosted germinating energy, improved germination, elevated fresh weight, and increased shoot length. In addition, fresh weight yield significantly increased with magnetic field treatment. Sensory evaluation confirmed superior quality, with higher scores for sprouts exposed to the magnetic field (Hieu et al., 2025). Germination is the process in which the metabolically dormant seed becomes metabolically active leading to successful growth and establishment of a plant. The process of germination is thought to be initiated by the activity of hormones and/or other signalling molecules. These substances can then trigger a chain of signalling events that culminates in the emergence of the radicle. This signalling pathway likely involves alterations in the activity of key regulatory genes, whose protein and enzyme products are essential for starting or stopping germination. Nevertheless, the specific cellular and molecular processes that lead to the commencement of germination (radicle emergence) are not yet fully understood. The act of subjecting seeds to a magnetic field stands out as a secure and economical potential physical treatment administered before planting. This method aims to bolster plant growth and enhance the establishment of a robust crop stand following germination. When considering seed technology, the application of physical methods to improve plant output provides merits over standard chemical-based treatments. (Talei et al., 2013) indicted that germination is a key process in plants′ phenological cycles. (Rice and Dyer, 2001). However, the direct consequences of aging inside the seed pool have received little attention, though the possible demographic costs of such a strategy (e.g., seed bank mortality or delayed reproduction) are well understood. Accelerating this process could lead to improvement of the seedling growth as well as the cultivation efficiency. By applying a magnetic field to the seeds of a rice variety, researchers analyzed the resulting

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biological effects on their sprouting behaviour. Specifically, they measured seed germination rate, what proportion of them successfully grew, and the average time it took for germination to commence. The outcome of this magnetic treatment was that all the seeds began to grow within three days, with an average germination time of just over two days. According to (Vashisth and Nagarajan, 2010) exposing chickpea and 1-month-old maize seeds to static magnetic fields led to noticeable improvements in germination rates, seedling strength, and the development of both shoots and roots. (Florez et al., 2007) and (Carbonell et al., 2011) observed that subjecting maize seeds to a magnetic field strength of 100 mT for a duration of 2 hours can stimulate metabolic activity in the seeds.(Shine et al., 2011) reported that treatment of magnetic field 50 to 200 mT were more effective in increasing most of the seedling parameter. Seed vigor is an indicator of successful crop establishment and long-term productivity. Instead of relying solely on chemical treatments, physical seed enhancement techniques offer a promising alternative to develop innovative biotechnology-based solutions for the expanding global seed industry (Araújo et al., 2016). (Pasitvilaitham et al., 2023) revealed that the strength of a magnetic field influences how well rice plants grow. Specifically, magnetic field intensities ranging from 14 to 65 millitesla can potentially enhance the overall mass of the rice. The strongest relative shoot to root growth (a ratio of 1:2.4) was observed when a 65 mT magnetic field was applied, with shoots developing more slowly compared to the roots (1:1.5). Conversely, a stronger magnetic field of 343 mT resulted in the greatest shoot/root ratio. Applying physical techniques to boost seed germination and seedling strength provides environmentally sustainable benefits and the potential for large-scale implementation. Among the promising strategies is the use of magnetic field treatment. Seed treatments with magnetic field resulted in enhanced production of reactive oxygen species (ROS) (Shine et al., 2011). There are many physiological, biophysical and molecular changes that occur due to magnetic stimulation in plants, but basis of magneto-reception is unclear. The enhanced characteristics of plant roots resulting from magnetic treatment indicate its potential application in real-world agriculture, specifically for rain-dependent cultivation. This method facilitates the uptake of water from deeper soil levels and, unlike chemical treatments, leaves no lingering impact. Consequently, this approach can bolster organic farming practices. Magnetic field technique is intended to increase germination of rice seeds because of its simplicity and efficacy in improving germination percentage and establishment of seedlings, in additions shoot and root length, without generating adverse effects on environment.

MATERIALS AND METHODS

Experiment site: A field experiments were conducted during 2024 season at Tag Elzz Agric. Res. Stat., ARC., and the Laboratory of Seed Technology Research Department, Dakahlia Governorate, Field Crops Research Institute, Agricultural Research Center, during 2024 to determine the effect of magnetic field and two rice seed lots viz., fresh and old (2 years old) seed lot on rice seedling parameters and field emergence. Table 1 observed the initial germination and moisture content for rice seed lots

Table 1. Initial germination and moisture content for rice seed lots

Rice seed lots	Germination %	Moisture content %
Old lot (Carry over)	85	7.7
New lot (Fresh lot)	98	7.7

A. Magnetic field treatments:

Table 2 presented the magnetic field treatments. T1. Control, T2. 50 mT (Millitesla) 2h static, T3. 50 mT (Millitesla) 5 min 2h pulse, T4. 100 mT (Millitesla) 2h static, and T5. 100 mT (Millitesla) 5 min 2h pulse.

Table 2. The magnetic field treatments

	Treatments	Durations	Cycle
T1.	Control (untreated)	Nonexposed seeds	-
T2.	50 mT 2 hours	2hours	Static
T3.	50 mT 2 hours	5 min on/off (pulse)	10 cycles
T4.	100 mT 2 hours	2hours (pulse)	Static
T5.	100 mT 2 hours	5 min on/off (pulse)	10 cycles

100 mT. (Millitesla)= 1000 Gauss.

B. Rice seed lots: fresh lot and old seed lot (2 years old)

Seed materials: Fresh and two-year-old seed samples originating from rice lots of the Sakha 108 variety were obtained from the Central Administration for Seed Production, which manages both newly harvested and stored seeds (those kept for two years). Following the removal of debris, dust, damaged seeds, and any other non-seed materials, the selected seeds underwent a five-minute soaking in a five percent sodium hypochlorite (NaClO) solution. This step was taken to prevent fungal growth. Following this, the initial germination rate and moisture level of the seeds were measured. The experiments were conducted in, May 2024.

Studied traits:

Germination percentage (GP): Eight replications of 50 seeds of each treatment were planted kept at 25 C° in an incubated chamber for 14 days. germination percentage was counted after 14 days according to (ISTA, 2009). GP% = Number of normal seedling /total number of seeds × 100. In each experimental repetition, ten typical seedlings were selected for measurement. Specifically, their shoot length (cm), root length (cm), total seedling length (cm), and seedling dry weight (g) were quantified following the methodology outlined by (Krishnasamy and Seshu, 1990). Seedling length was recorded in centimeters: It was recorded by the average of random ten seedlings at the end of germination test.

Seedling dry weight (g): Fourteen days following planting, a selection of ten robust seedlings underwent a drying process in a heated air oven set at 85°C for a duration of 12 hours. This procedure aimed to ascertain their dry weight, adhering to the methodology outlined by (Krishnasamy and Seshu, 1990). Subsequently, the seedling vigor index (SVI) was calculated using the formula provided by (Abdul-Baki et al., 1973):

SVI 1 = Germination percentage × Seedling length.

SVI 2 = Germination percentage × Seedling dry weight.

Proline content determination: Proline was quantified in 100 mg of leaf tissue by first extracting it with ninhydrin reagent in 3% (w/v) aqueous sulfosalicylic acid (Bates et al., 1973). Following the separation of the organic toluene phase, the absorbance of the resulting red color was read at 520 nm, and the proline concentration (mg/g FW) was determined using a calibration curve. Field emergence % (FE): The experimental field at Tag El-Ezz Agricultural

Research Station in Dakahlia Governorate, one hundred seeds of each variety were sown in three replications in a Randomized Complete Block Design (RCBD). The total number of seedlings in the field was counted when the emergence was complete or when there was no further addition in total emergence. Statistical procedures: Using Two-way analysis of variance (ANOVA), which was performed using the software (Statistix 8.1) as published by (Gomez and Gomez, 1984). Least significant difference (LSD) was calculated at 5% level of probability for comparing between means of treatments.

RESULTS AND DISCUSSION

Results

A. Magnetic Field

As shown in Tables 3 and 4 exhibits the impact of different magnetic field and rice seed lots on germination percentage, shoot length, root length and total seedling length, seedlings dry weight, seedling vigor index 1, seedling vigor index 2, field emergence and proline content. Highly significant differences among magnetic field treats were observed. Compared to the control, seeds treated with a 50 mT magnetic field had a better germination rate, which was the lowest in the control group. The most substantial increases in root length, shoot length, and seedling length were observed in seeds treated with magnetic fields in T2 and T3, surpassing control T1 and magnetic field treatment T4. Treatments involving magnetic and electric fields also resulted in greater fresh and dry weight than the control. The research also indicated that rice varieties possessed higher vigour, as evidenced by their greater vigour index 1 and 2. Response at low intensity of magnetic field as compared to control. Different static and pulse field enhanced the germination potential and seedling establishment in both lots.

B. Rice seed lots:

With respect to rice seed lots performance, it was found that the fresh lot significantly differed in germination percentage, shoot length, root length and total seedling length. Data presented in Table 3 showed that fresh lot surpassed old lots in all studied traits. Observed data in Tables 3 and 4 showed that T3 improved seedling dry weight, and seedling vigor index 1. While T4 increased the seedling vigor through high value of seedling vigor index 2. In addition, T5 enhanced the seedling vigor 2 and field emergence. In general, both static and pulse field with low intensive improving the seedling vigor and potential germination in different lots.

Table 3. Impact of magnetic field and seed lots on germination percentage, shoot, root length and total length of rice seedlings.

Treatments A. Magnetic Field	Germination percentage (%)	Shoot length (cm)	Root length (cm)	Seedling length (cm)
Control	93.2	9.3	11.8	21.1
50 mT 2h	98.8	10.8	14	24.8
50 mT 5 min 2h	96.2	10.6	13.2	23.8
100 mT 2h	97.4	10.5	12.8	23.3
100 mT 5 min	94.0	10.0	12.4	22.4
F test	**	**	**	**
LSD 0.05	1.443	0.139	0.167	0.38
B. Rice Lots				
Fresh lot	91.2	9.7	13.5	22.8
Old (carry over seed)	85.0	9.8	12.8	22.6
F test	**	**	**	**
AXB	**	**	**	**

Table 4. Seedling dry weight (gm), seedling vigor index 1, seedling vigor Index 2, field emergence (%) and proline (mg/fresh weight).

Treatments	Seedling dry weight (g)	Seedling Vigor Index 1	Seedling Vigor Index 2	Field emergence (%)	Proline content mg/fresh weight
A. Magnetic Field					
T1: Control	0.116	1892.0	11.068	84.2	0.3633
50 mT 2h	0.119	1979.0	10.478	85.3	0.455
T2: 50 mT 2 hours	0.119	2059.0	10.301	84.8	0.497
100mT 2h	0.118	1977.0	10.366	84.7	0.5917
T3: 50 mT 5 min	0.116	1914.9	9.747	82.0	0.662
F test	**	**	**	**	**
LSD 0.05	1.34	40.612	0.199	1.62	0.022
B. Rice Lots					
Fresh lot	0.1203	2084.1	10.975	89.0	0.494
Old (carry over seed)	0.1187	1845.9	9.809	83.2	0.533
F test	**	**	**	**	**
AXB	**	**	**	**	**

Interactions effects:

Data presented in Tables 5 and 6 revealed to the interaction effects among different magnetic fields and rice seed lots on G%, shoot length, root length, seedling length, seedling dry weight (gm), seedling vigor index 1, seedling vigor index 2 and field emergence (%). Highly significant increase due to the interaction between the two factors. At the T3: 50 mT 5 min for two hours of magnetic field recorded the highest values and improvement in seedling quality in terms of GP%, shoot, root and seedling length. The highest values were produced by fresh lots with different magnetic fields.

Table 5. Interaction effects of magnetic field and seed lots on germination%, shoot, root length, and seedling length.

Magnetic field	Seed lots	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling length (cm)
T1: Control	Fresh	90.5	9.8	12.8	22.6
	Old	85.0	9.3	10.7	20.0
T2: 50 mT 2 hours	Fresh	89.3	9.5	12.8	21.1
	Old	87.0	9.9	13.5	23.2
T3: 50 mT 5 min	Fresh	94.0	10.3	14.5	24.8
	Old	86.6	10.9	12.8	23.7
T4: 100 mT 2hours	Fresh	93.2	9.8	13.9	23.7
	Old	87.3	9.8	11.7	21.5
T5: 100 mT 5 min	Fresh	91.3	9.4	13.4	22.8
	Old	88.7	8.8	13.3	22.1
F test		**	**	**	**
LSD 0.05		2.04	0.197	0.24	0.54

Table 6. Interaction effects of magnetic field and seed lots on seedling dry weight (SDW), seedling vigor index1, seedling vigor index 2 field emergence and proline content.

Magnetic field	Seed lots	Seedling dry weight (g)	SVI1	SVI2	Field emergence	Proline content (mg)
T1: Control	Fresh	0.128	1985.6	11.8	89.0	0.397
	Old	0.121	1800.3	10.4	83.0	0.330
T2: 50 mT 2 hours	Fresh	0.119	1944.5	10.7	86.0	0.487
	Old	0.118	2015.3	10.3	86.0	0.423
T3: 50 mT 5 min	Fresh	0.117	2239.5	10.6	84.7	0.507
	Old	0.122	1880.2	10.0	88.3	0.487
T4: 100 mT 2 hours	Fresh	0.118	2194.2	11.1	79.3	0.613
	Old	0.118	1760.4	9.7	90.0	0.570
T5: 100 mT 5 min	Fresh	0.117	2056.5	10.7	89.3	0.663
	Old	0.115	1773.3	9.0	74.7	0.660
F test		**	NS	**	**	*
LSD 0.05		1.89	-	0.28	2.297	0.031

SVI1: seedling vigor index1, SVI2: seedling vigor index 2

Table 7 presents the correlation coefficients for all the evaluated seed technology characteristics of the plants.

Notably, the attributes associated with seed germination exhibited significant positive correlations. The strongest correlations were observed between germination percentage and field emergence (0.992), and this relationship was most closely linked to seedling length and seedling vigor index.

Table 7. Simple correlation coefficients of seed quality features of rice seeds.

Treatments	Germination %	Seedling length	Seedling dry weight	Seedling vigor index1	Seedling vigor index2	Proline content
Seedling length	0.095	1				
Seedling dry weight	0.325	-0.394	1			
Seedling vigor index1	0.802	0.670	-0.002	1		
Seedling vigor index2	0.917	-0.092	0.675	0.624	1	
Proline content	-0.138	0.381	-0.584	0.127	-0.347	1
Field emergence %	0.992	0.131	0.335	0.816	0.915	-0.119

Discussions

High vigor seeds are a substitute for crop establishment and sustained productivity (Finch et al., 2016). The results showed the main cause of the decrease in carry over seed of rice crop growth is slowing germination and seedling establishment. Rice is often propagated using seeds or seedlings, and the germination of seeds is influenced by environmental conditions and seed architecture that impact the embryo's growth potential (Koornneef et al., 2002). Various techniques, such as hot water treatment, cold plasma exposure, magnetic field application, and nanomaterial-based seed coatings, are being explored to enhance seed germination and promote plant development. This study highlights the advantages and limitations of each method and emphasizes the importance of integrating these strategies into comprehensive crop management systems. Sustainable farming practices can benefit from these environmentally friendly physical seed treatments, which help increase agricultural output while preserving ecological balance. Seeds exposed to a 50 mT magnetic field demonstrated improved enzymatic activity, higher germination rates, increased seedling length, greater seedling dry weight, and enhanced vigor indices. Seeds treated with a magnetic field are likely to play an essential part in the creation of food free of harmful and chemical residues. The utilization of physical techniques for seed invigoration is described, along with a critical analysis of the benefits and limitations. Several crucial germination-related indicators, including germination percentage, root and shoot length, proline content, and field emergence, were assessed under various electromagnetic field exposure conditions (static and pulse frequency) to examine the germination (Radhakrishnan, 2019). (Pszczółkowski et al., 2023) and (Yadav et al., 2025) reported that in sustainable agricultural practices pre sowing is useful and environmentally friendly, especially in the seed production in ecological systems. The study used both aged (2 years old) and fresh seed to explore the effect of seed age on seedling vigor and competitive abilities. Aged seed displayed germination delays, reducing plant growth and biomass (Rice and Dyer, 2001). Seed treatments are essential for maximizing crop yields, promoting plant health and growth. This work provides an overview of eco-friendly physical seed treatment that complements environmentally sensitive farming methods. In summary, rice seed exposure to static and pulse with different time had a positive effect on enzymatic activity and seedling growth parameters for fresh and aged rice seeds 2 years old. The mechanisms of action of magnetic fields in plants are currently unknown, despite numerous theories being offered. Prospects for applying these methods to meet the demands of farmers, trade markers, and seed technologists will also be emphasized.

CONCLUSIONS

The findings revealed that exposing rice seeds to a 50 mT magnetic field for two hours, whether static or pulsed, significantly enhanced various germination characteristics compared to untreated seeds. Specifically, this exposure led to the highest levels of germination rate, seedling length, seedling dry weight, and seedling vigor indices for both freshly harvested and older seeds. Notably, both consistent and intermittent magnetic field treatments positively influenced the growth parameters of these rice seed batches. Seeds subjected to magnetic field treatment demonstrated a considerable improvement in germination and growth, suggesting a potentially vital role for this technique in producing food and seeds free from chemical residues, which is advantageous for human consumption and seed production.

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إنبات تقاوي الأرز وتأثرها بالمجال المغناطيسي والتقاوي المخزنة

عبدالمجيد محمد سعد كشك و هبه حسن مصطفي العجمي

قسم بحوث تكنولوجيا البذور - معهد بحوث المحاصيل – الحقلية - مركز البحوث الزراعية

الملخص

من المعروف أن تعريض تقاوي الأرز قبل الزراعة لمجال ثابت وكهرومغناطيسي يغير ويحفز سلسلة من التأثيرات البيوكيميائية والبيولوجية داخل البذرة. تهدف الدراسة الحالية إلى تحديد تأثير المجال المغناطيسي قبل الزراعة للوطات تقاوي الأرز المخزنة عامين والحديثة على الإنبات والتكشف الحقلي. أيضا دراسة تأثير عمر البذور وقوة البادرات وقدرتها التنافسية. لذلك أجريت تجربة علي لوطين من تقاوي الأرز (تقاوي حديثة وتقاوي قديمة مخزنة عامين)، وخمسة معاملات من المجال المغناطيسي، هي: كنترول بدون معاملة ، 50 مللي تسلا لمدة ساعتين ،٥٠ مللي تسلا متقطع كل خمس دقائق لمدة ساعتين ،١٠ مللي تسلا لمدة ساعتين و ١٠٠ مللي تسلا متقطع خمس دقائق لمدة ساعتين. أشارت النتائج إلى أن أعلى نسبة إنبات وطول الريشة وطول الجذير بشكل ملحوظ في معاملة ٥٠ مللي تسلا (تيار ثابت أو متردد خمس دقائق لفترة ساعتين) مقارنة بمعاملات المجال المغناطيسي الأخرى والكنترول. فيما يتعلق بجودة التقاوي، تم تسجيل أعلي نسبة إنبات للتقاوي صنف سخا ١٠٨، طول الريشة، طول الجذير وطول البادرة، الوزن الجاف للبادرة و دليل قوة البادرة ١، دليل قوة البادرة ٢، في معاملة ٥٠ مللي تسلا مقارنة بالمعاملات الأخرى. أظهرت النتائج ارتباط طردي قوي بين نسبة الإنبات والصفات التكنولوجية للبادرات والتكشف الحقلي ومحتوي البرولين. كما تفيد هذه التقنية في تحسين التقاوي المخزنة ببنك الجينات والتقاوي التي لم يتم بيعها في المواسم السابقة كما تفيد في تحسين جودة التقاوي للمزارع وشركات التقاوي لما لها من تأثير واضح علي النشاط الانزيمي والبيوكيماوي.لذلك، توصي الدراسة باستخدام تقنية المجال المغناطيسي الثابت والمتردد لتحسين نمو بادرات الأرز سواء الحديثة الحصاد أوالمخزنة عامين.