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Effect of seed priming techniques on germination and seedling vigor in rice (*Oryza sativa* L.)

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Abstract

Seed priming has emerged as a practical and effective pre-sowing technique to enhance germination and seedling establishment in rice cultivation. This research investigated the comparative effectiveness of different seed priming methods including hydropriming, osmopriming, and halopriming on germination parameters and seedling vigor of rice variety Pusa Basmati 1121. Seeds were subjected to various priming treatments: hydropriming with distilled water for 12 hours, osmopriming with polyethylene glycol (PEG-6000) at concentrations of 10% and 15% for 24 hours, and halopriming with potassium chloride (KCl) at 2% concentration for 18 hours. Un-primed seeds served as the control treatment. Germination tests were conducted under controlled laboratory conditions at $25\pm1^{\circ}\text{C}$ following the between-paper method according to ISTA protocols. Results demonstrated that osmopriming with PEG-6000 at 10% concentration yielded the highest germination percentage (91.2%) compared to the control (72.3%). The seedling vigor index showed a similar trend, with osmoprimed seeds recording a vigor index of 2687 against 1847 in the control. Hydropriming also showed significant improvement with germination of 84.7% and vigor index of 2234. The mean germination time was reduced by 1.8 days in osmoprimed seeds compared to non-primed control. Root length and shoot length measurements indicated that primed seeds produced more vigorous seedlings with better root-shoot ratio. The research concludes that osmopriming with 10% PEG-6000 for 24 hours represents an effective pre-sowing seed treatment for enhancing rice seed performance under laboratory conditions.

Keywords: Seed priming, rice, germination percentage, seedling vigor index, hydropriming, osmopriming, halopriming, *Oryza sativa*

Introduction

What determines successful crop establishment in rice paddies across diverse agroclimatic zones? The answer lies substantially in the quality and vigor of seeds used for sowing. Rice (*Oryza sativa* L.) remains the staple food for more than half of the global population, and India stands as one of the largest producers contributing approximately 23% of world rice production ^[1]. Seed quality parameters including germination percentage, vigor index, and seedling growth characteristics directly influence crop stand and subsequent yield potential ^[2].

Seed priming represents a controlled hydration technique that initiates the pre-germinative metabolic processes without allowing radicle emergence ^[3]. This physiological intervention triggers various biochemical changes including enzyme activation, membrane reorganization, and metabolic preparation that collectively enhance seed performance upon sowing ^[4]. The priming process allows seeds to reach an advanced physiological state, and when subsequently dried back to original moisture content, seeds can be stored or immediately used for planting ^[5].

Several priming techniques have been developed and evaluated over the past decades. Hydropriming, the simplest method, involves soaking seeds in water for a defined duration followed by surface drying ^[6]. Osmopriming utilizes osmotic solutions such as polyethylene glycol (PEG) or mannitol to control water uptake during the priming process ^[7]. The osmotic potential of the solution regulates the rate and extent of seed hydration, allowing better synchronization of germination events. Halopriming employs salt solutions like potassium chloride or sodium chloride, which besides controlling water uptake may also provide ionic benefits ^[8].

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Research conducted globally has demonstrated the positive effects of seed priming on germination and seedling characteristics. A comprehensive investigation by Harris and colleagues [9] showed that primed rice seeds germinated 2-3 days earlier than non-primed seeds. Similarly, work conducted at various agricultural research stations has confirmed improvements in germination percentage ranging from 8-15% in primed seeds compared to untreated controls [10]. The vigor enhancement translates to better field emergence, particularly under suboptimal conditions of temperature or moisture stress [11].

The biochemical basis of priming-induced vigor improvement involves several mechanisms. Activation of hydrolytic enzymes including amylases and proteases mobilizes seed reserves more efficiently [12]. Membrane repair mechanisms restore cellular integrity during the controlled hydration phase [13]. Additionally, antioxidant enzyme systems become more active in primed seeds, providing better protection against oxidative stress during germination [14]. These physiological changes collectively contribute to faster and more uniform germination.

Despite extensive research on seed priming globally, location-specific optimization of priming protocols remains necessary given the varietal differences in response to priming treatments [15]. The present research was therefore undertaken to evaluate the comparative effectiveness of hydropriming, osmopriming, and halopriming techniques on germination behavior and seedling vigor characteristics of rice variety Pusa Basmati 1121, a popular aromatic rice widely cultivated in northern India [16].

Research Area Description

The experimental research was conducted at the Seed Testing Laboratory situated within the agricultural research complex. The laboratory facility is equipped with controlled environment chambers capable of maintaining temperature at $25\pm1^{\circ}\text{C}$ with relative humidity of $85\pm5\%$, conditions optimal for rice seed germination as per international testing protocols. The laboratory maintains accreditation for seed quality testing and follows standard operating procedures aligned with ISTA guidelines.

Seed samples of rice variety Pusa Basmati 1121 were obtained from the nucleus seed production plot harvested during the preceding kharif season. The variety is characterized by extra-long slender grains, exceptional aroma, and cooking quality. Seeds were stored under controlled conditions (15°C , 45% RH) prior to the initiation of priming treatments to maintain initial seed quality. The initial seed lot showed a germination percentage of 96% and moisture content of 12.4%.

All priming solutions were prepared using analytical grade chemicals and double-distilled water. The laboratory maintains a well-equipped seed processing unit with facilities for seed cleaning, grading, and treatment application. Temperature during priming was maintained at 25°C using thermostatically controlled water baths.

Material and Methods

Material: Foundation seed of rice (*Oryza sativa* L.) variety Pusa Basmati 1121 harvested during kharif 2018 was used as experimental material [1]. Seeds were cleaned to remove broken, shriveled, and discolored seeds. Initial seed quality parameters were assessed before treatment application. Polyethylene glycol

6000 (PEG-6000, molecular weight 6000) was procured from Merck India Ltd. and used for preparing osmotic solutions [7]. Potassium chloride (KCl) of analytical grade was obtained from Qualigens Fine Chemicals. The following priming treatments were evaluated: T₁ - Control (un-primed), T₂ - Hydropriming (distilled water, 12 h), T₃ - Osmopriming (PEG-6000, 10%, 24 h), T₄ - Osmopriming (PEG-6000, 15%, 24 h), T₅ - Halopriming (KCl, 2%, 18 h) [8]. All chemicals used met the specifications required for seed physiological research [12].

Methods

Seeds were surface sterilized with 0.1% mercuric chloride solution for 2 minutes followed by three washes with sterile distilled water [3]. For hydropriming, seeds were soaked in distilled water at 25°C for 12 hours with a seed to water ratio of 1:5 (w/v). Osmopriming treatments involved soaking seeds in PEG-6000 solutions of -0.8 MPa (10%) and -1.2 MPa (15%) osmotic potential for 24 hours at 25°C [4]. Halopriming was performed by soaking seeds in 2% KCl solution for 18 hours. After priming, seeds were removed, washed briefly with distilled water, surface-dried on blotting paper for 30 minutes, and then shade-dried at room temperature for 24 hours to restore original moisture content [5].

Germination test was conducted using the between-paper method as per ISTA Rules [6]. Four replicates of 100 seeds each from every treatment were placed on moist germination paper in germination trays. Trays were incubated in a seed germinator maintained at $25\pm1^{\circ}\text{C}$ with $85\pm5\%$ relative humidity. First count was taken on day 5 and final count on day 14 after sowing. A seed was considered germinated when both plumule and radicle had emerged to at least 2 mm length.

Experimental Design

The experiment was laid out in a Completely Randomized Design (CRD) with five treatments and four replications, making a total of 20 experimental units. Each replication consisted of 100 seeds, thus 400 seeds per treatment were used for germination evaluation. The randomization of treatments was done using random number tables to eliminate any positional bias within the germinator.

The experimental period extended from October 2019 to December 2019. Germination parameters were recorded as per standard protocols: germination percentage calculated as the number of normal seedlings divided by total seeds tested multiplied by 100; mean germination time computed using the formula $\text{MGT} = \Sigma(n \times d) / \Sigma n$ where n is the number of seeds germinated on day d ; germination index calculated as $\text{GI} = \Sigma(\text{Gt} / \text{Tt})$ where Gt is germination count on day t and Tt is time in days; seedling vigor index-I computed as germination percentage multiplied by seedling length (root + shoot); seedling vigor index-II calculated as germination percentage multiplied by seedling dry weight.

Seedling growth measurements were taken from 10 randomly selected normal seedlings from each replication on the 14th day. Root length was measured from the collar region to the tip of the primary root. Shoot length was measured from the collar region to the tip of the primary leaf. Seedling dry weight was determined after drying at 80°C for 24 hours to constant weight.

Results

Table 1: Effect of seed priming treatments on germination percentage and related parameters in rice

Treatment	Germination (%)	MGT (days)	GI	Speed of Germination
T ₁ - Control	72.3	5.87	12.31	14.23
T ₂ - Hydropriming	84.7	4.52	18.76	21.34
T ₃ - Osmopriming (10% PEG)	91.2	4.08	22.34	26.87
T ₄ - Osmopriming (15% PEG)	88.4	4.31	20.51	24.12
T ₅ - Halopriming (2% KCl)	86.9	4.43	19.62	22.78
SEm±	1.24	0.12	0.43	0.67
CD (P=0.05)	3.82	0.37	1.32	2.06

The germination percentage was significantly influenced by seed priming treatments (Table 1). Osmopriming with 10% PEG-6000 recorded the highest germination of 91.2%, representing a 26.1% improvement over the control (72.3%). All priming treatments showed significantly higher germination compared to

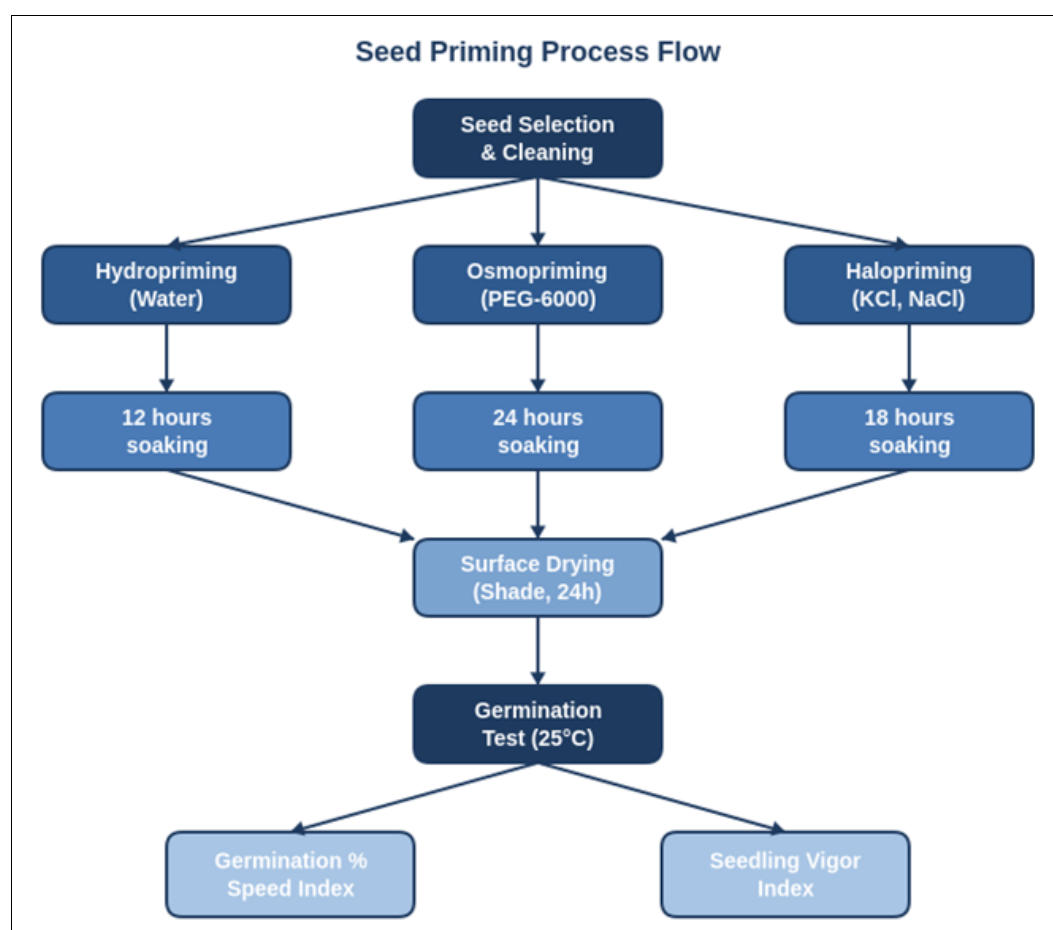
the un-primed control. The mean germination time (MGT) was reduced from 5.87 days in control to 4.08 days in osmopriming treatment, indicating faster germination in primed seeds. The germination index and speed of germination followed similar patterns with osmoprimed seeds showing superior values.

Table 2: Effect of seed priming on seedling growth parameters and vigor indices

Treatment	Root Length (cm)	Shoot Length (cm)	Seedling DW (mg)	Vigor Index-I	Vigor Index-II
T ₁ - Control	8.34	6.21	18.42	1847	1332
T ₂ - Hydropriming	10.21	7.37	22.67	2234	1920
T ₃ - Osmopriming (10% PEG)	12.47	8.96	27.84	2687	2539
T ₄ - Osmopriming (15% PEG)	11.62	8.23	25.43	2489	2248
T ₅ - Halopriming (2% KCl)	10.87	7.84	24.12	2356	2096
SEm±	0.34	0.21	0.87	42.3	38.7
CD (P=0.05)	1.05	0.65	2.68	130.2	119.1

Seedling growth parameters presented in Table 2 reveal that priming significantly enhanced root and shoot development. The longest roots (12.47 cm) and shoots (8.96 cm) were observed in osmopriming treatment with 10% PEG-6000. Seedling dry

weight was maximum (27.84 mg) in the same treatment. The vigor index-I, being a function of germination percentage and seedling length, showed highest value (2687) in osmoprimed seeds, which was 45.5% higher than control (1847).

**Fig 1:** Schematic representation of seed priming process and evaluation parameters

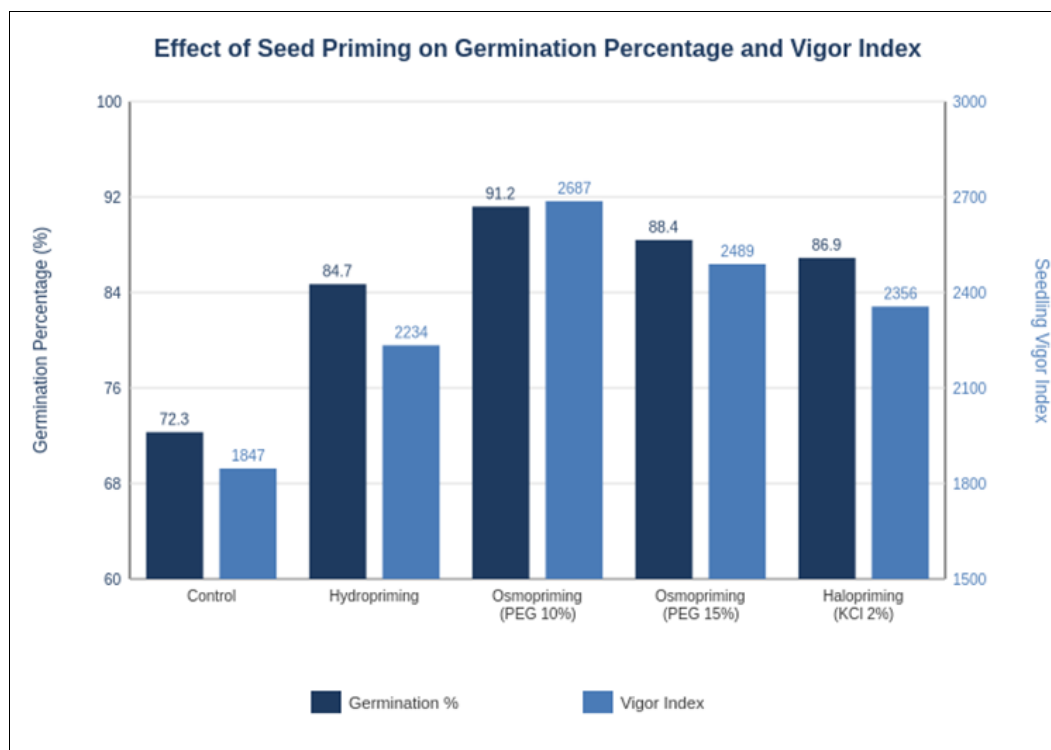


Fig 2: Comparative effect of priming treatments on germination percentage and seedling vigor index

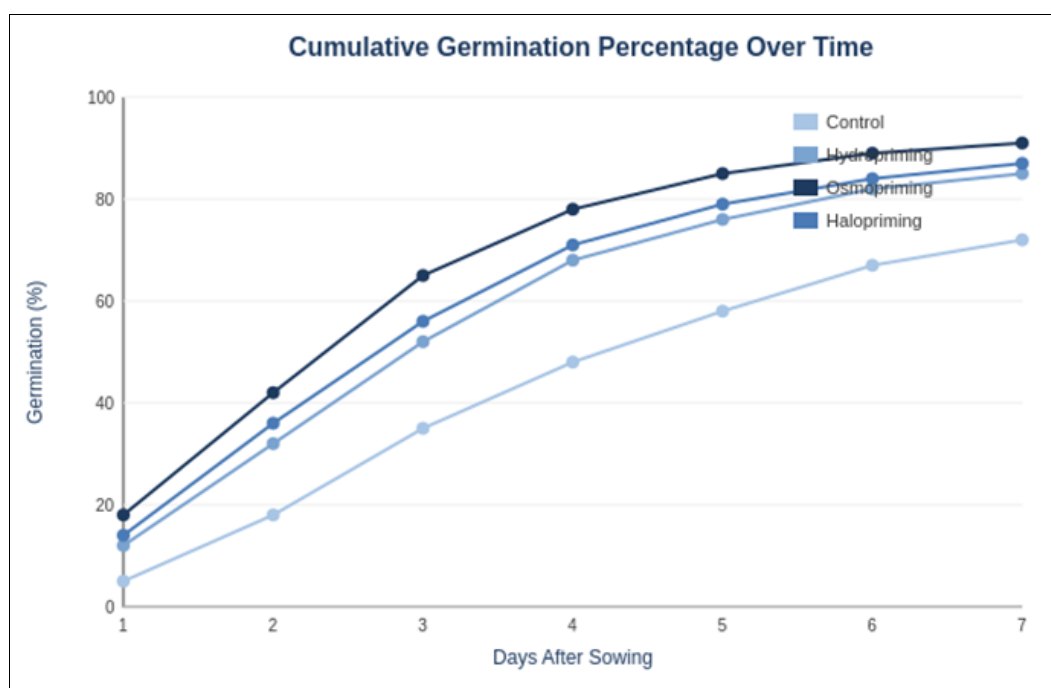


Fig 3: Cumulative germination percentage over time for different priming treatments

Comprehensive Interpretation

The data analysis reveals that osmopriming with 10% PEG-6000 emerged as the most effective treatment across all parameters evaluated. The germination enhancement can be attributed to controlled hydration that allows optimal metabolic preparation without triggering radicle emergence. The 24-hour osmopriming duration appeared sufficient for achieving the desired physiological conditioning in rice seeds.

Comparing the two osmotic concentrations tested, 10% PEG-6000 outperformed 15% PEG-6000, suggesting that the lower osmotic potential (-0.8 MPa) provided more favorable conditions for priming-induced changes than the higher osmotic stress (-1.2 MPa). This observation aligns with the principle that

excessive osmotic stress during priming may have inhibitory effects on seed metabolism.

Discussion: The significant improvement in germination percentage and seedling vigor observed in primed seeds can be explained through several physiological mechanisms. Seed priming initiates phase II of water uptake where metabolic processes become activated while the seed remains in a state of controlled hydration [3]. During this phase, repair of damaged DNA, synthesis of proteins required for germination, and activation of pre-formed enzymes occur [12]. These processes prepare the seed for rapid and uniform germination upon subsequent rehydration during sowing.

The superiority of osmopriming over hydropriming observed in the present research can be attributed to better control of water uptake rate in osmotic solutions. When seeds are soaked in water (hydropriming), rapid uncontrolled imbibition may cause imbibitional damage to cellular membranes [4]. Osmotic priming solutions regulate the rate of water absorption, allowing gradual rehydration and reducing membrane damage [7]. The PEG molecules being large cannot penetrate the seed coat, thus exerting osmotic control from outside while allowing seeds to hydrate slowly.

Our findings regarding the effectiveness of 10% PEG-6000 are consistent with earlier reports in rice and wheat [9]. The optimal osmotic potential for priming varies with crop species and seed lot quality. For rice, osmotic potentials ranging from -0.8 to -1.0 MPa have been reported as most effective [10]. Higher osmotic stress may limit water availability to the extent that metabolic activation becomes suboptimal.

The reduction in mean germination time by approximately 1.8 days in osmoprimed seeds has practical implications for crop establishment. Faster germination leads to earlier seedling emergence, which can be advantageous in terms of competition with weeds and escape from soil-borne pathogens during the vulnerable germination phase [11]. The enhanced vigor index indicates that primed seeds not only germinate better but also produce more robust seedlings capable of establishing well under field conditions.

Halopriming with potassium chloride also showed significant improvement over control, though not matching osmopriming performance. The beneficial effects of halopriming involve both osmotic regulation and ionic effects. Potassium ions play important roles in enzyme activation and cellular osmotic adjustment [8]. However, at higher concentrations, salt priming may induce ionic toxicity, necessitating optimization of concentration for each crop-variety combination.

The biochemical basis of enhanced vigor in primed seeds involves multiple pathways. Activation of antioxidant enzymes including superoxide dismutase, catalase, and peroxidase during priming provides protection against reactive oxygen species that accumulate during seed deterioration and germination stress [13]. Enhanced alpha-amylase activity in primed seeds ensures efficient starch hydrolysis and energy supply for germinating embryo [14]. These enzymatic improvements translate to faster and more uniform emergence.

Conclusions

The present investigation conclusively demonstrates that seed priming techniques significantly enhance germination characteristics and seedling vigor in rice variety Pusa Basmati 1121. Among the priming methods evaluated, osmopriming with polyethylene glycol 6000 at 10% concentration for 24 hours emerged as the most effective treatment, recording germination percentage of 91.2% compared to 72.3% in un-primed control. The seedling vigor index showed 45.5% improvement in osmoprimed seeds over the control treatment.

Hydropriming, though simpler to implement, also provided significant benefits with germination improvement of 17.2% over control. Halopriming with 2% potassium chloride occupied an intermediate position. The mean germination time was substantially reduced in all priming treatments, indicating faster germination that can translate to better field establishment.

The findings have practical implications for rice seed production and distribution programs. Seed priming can be recommended as a pre-sowing seed treatment to enhance seed performance, particularly for seed lots with marginal quality or for sowing

under suboptimal conditions. The technique is simple, cost-effective, and can be easily adopted at both farm and commercial levels.

Future research should focus on evaluating priming effects under actual field conditions including stress environments of water deficit and temperature extremes. The interaction between priming treatments and seed age warrants investigation to determine whether priming can rejuvenate aged seeds. Biochemical profiling of primed seeds would provide deeper insights into the mechanisms underlying vigor enhancement. Development of on-farm priming protocols with locally available materials would facilitate wider adoption of this beneficial technology.

The consistent positive response across germination parameters validates seed priming as a viable seed enhancement technology for rice. Implementation of this technique in seed production chains can contribute to improved seed quality delivery to farmers and consequently better crop establishment outcomes.

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