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Seed Dormancy and Germination Potential of Coastal Rice Landraces in Bangladesh: Implications for Climate-Resilient Cultivation

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Abstract: The coastal regions of Bangladesh host a rich diversity of Aman rice landraces, which are crucial for local agriculture but are highly vulnerable to natural disasters like cyclones and floods. Specifically, local landraces often experience flooding during grain filling and maturation stages, and sprouts in the field lead to a severe loss of yield. Seed dormancy, which delays germination, is a key trait for escaping sprouting in the field during harvesting. However, there is lack of information on genetic variability in the existing rice landraces grown in the coastal area of Bangladesh. This study evaluated the seed dormancy of 28 local Aman rice landraces, plus four varieties from the Bangladesh Institute of Nuclear Agriculture and Bangladesh Rice Research Institute. Germination tests were conducted under controlled conditions, and an electrical conductivity (EC) test was used to assess seed vigor. The results showed that *Bari Mota*, *Tulsimala*, *Chinigura*, *Dishari*, and *Birindi* exhibited the highest dormancy rates, i.e., 100%, 100%, 99%, 99%, and 99%, respectively, while *BINA Dhan 10*, *Nona Bokra*, and *BINA Dhan 8* had the lowest dormancy rates, with values of 11%, 16%, and 24%, respectively. Priming treatments enhanced germination rates in some varieties; however, others, such as *Bari Mota* and *Tulsimala*, remained dormant, underscoring the variability in seed dormancy levels. Compared to non-priming, a significant improvement of germination was recorded in *BRRI dhan 41* (85.3% vs. 9%), *Motha mota* (84% vs. 8%), *Lal chikon* (74.6% vs. 1%), *Sadamota* (74.6% vs. 5%), and *Bashful* (53.3% vs. 3%). Altogether, our results suggest that local landraces are diverse in seed dormancy, and genotypes with high dormancy, such as *Bari Mota* and *Tulsimala*, can potentially be grown in the disaster-prone coastal areas. In contrast, these genotypes can be used for future breeding programs. Therefore, this study carries significant implications for rice cultivation in the coastal areas of Bangladesh.

Keywords: indigenous rice; dormancy; seed treatment; flood; priming treatment; climate-resilient

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1. Introduction

Rice (*Oryza sativa* L.), a member of the grass family Gramineae [1,2], is the most important crop in Bangladesh, covering 80% of the cultivable land and serving as a staple

food deeply embedded in the country's culture and economy [3]. However, the diversity of rice is shrinking since farmers are usually cultivating high-yielding varieties and hybrids.

The southern part of Bangladesh is a coastal area, which covers 32% of the land area, and its average elevation is between 3 and 6 m [4]. The coastal area of Bangladesh faces severe agricultural challenges such as waterlogging, soil salinity, and frequent cyclones [5]. Therefore, semi-dwarf HYV and hybrids are not adapted to this area during the *Aman* season (i.e., the rainfed rice cultivated between June and December), and thus, farmers primarily rely on local landraces [5,6]. These landraces are morphologically different and, therefore, may be more diverse genetically than modern cultivars [7]. However, they are under threat of extinction [8]. A loss of diversity would have significant implications for rice cultivation in the coastal area since the extinction of some genotypes would lead to the permanent loss of useful and unique genes such as genotypes with higher dormancy just after maturation.

When cyclones hit during the harvesting period of *Aman* season rice, the rice field is submerged with surge water, and the rice grain is often sprouted/germinated in the field, causing a serious loss of yield and quality of rice [9]. This pre-harvest sprouting poses a significant challenge to agriculture worldwide, affecting major grain-producing countries like Australia, Canada, China, Europe, Japan, South Africa, and the United States. This phenomenon results in considerable economic losses, with a global annual penalty estimated at one billion dollars [10]. Often, some rice grains carry dormancy that prevents germination. Therefore, it is important to identify the rice with dormancy among the rice grown in the coastal area. However, no studies have been carried out to examine this phenomenon yet.

Seed dormancy is generally an undesirable characteristic in crops where rapid germination and growth are required. Seed dormancy may be caused by certain properties, i.e., a hard seed coat to hinder the imbibition of water into seeds, the mobilization of reserve components, less enzymatic activities, or the combined actions of several of these factors [11]. Since many of these factors are determined by genetic factors, species or cultivars with dormancy demonstrate their properties under diverse environmental conditions, indicating the importance of identifying species or cultivars with this trait. However, seed dormancy can also be modulated by environmental parameters such as seed moisture and temperature [12]. The extensive domestication and breeding of crop species have ostensibly removed most dormancy mechanisms present in the seeds of their wild ancestors, although, under adverse environmental conditions, dormancy may reappear [13]. For instance, the seed dormancy of modern varieties disappeared after breeding [14–16].

The level of seed dormancy of genotypes also varies with both genetic and environmental control. Specifically, whether the seeds germinate or maintain dormancy is complex and governed predominantly by physiological and molecular processes [9]. Some rice varieties have a significant level of dormancy (i.e., do not germinate with weak dormancy-breaking treatment), while others may have dormancy that is easy to break [17,18]. These differences in dormancy could have significant implications when the seeds are subject to different levels of favorable environments for germination. For instance, rice seeds with a high level of dormancy may not sprout or germinate under water, while others will germinate within a few days or even hours. If moist conditions are encountered, a low dormancy level causes pre-harvest sprouting in rice crop. This decreases crop yield and negatively impacts downstream industrial processing [9].

Various methods have been used to break seed dormancy, with their suitability often depending on the species [19–21]. Presoaking seeds in HNO_3, 1 M H_2O_2, or GA_3 in 1000 ppm solution has been shown to promote seed germination. For rice seeds, the International Seed Testing Association (ISTA) recommends using 1 N HNO_3 for 24 h [21].

In the present study, seed dormancy was disrupted using a dormancy-breaking treatment, as recommended for rice, to evaluate true dormancy levels in the selected genotypes.

Rice cultivated in the coastal regions of Bangladesh exhibits remarkable genetic diversity and often retains its wild characteristics, including adaptability to challenging environmental conditions. Despite the importance of these traits, particularly seed dormancy, no comprehensive study has investigated pre-harvest sprouting in these landraces. The lack of research on the genetic variability and dormancy levels in this diverse and resilient germplasm represents a significant knowledge gap.

This study introduces an innovative approach to evaluating seed dormancy in local rice landraces, aiming to identify cultivars with the potential for breeding pre-harvest sprouting-resistant varieties tailored for sustainable coastal agriculture. Additionally, the selected landraces offer promising adaptability for cultivation in disaster-prone regions.

2. Materials and Methods

2.1. Germination Test

The experiment was conducted in the Agronomy Stress Laboratory at Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali, Bangladesh. Local rice was collected from the Agronomy Field Laboratory just after harvesting from the field. Seeds were collected immediately after harvest at 80% maturity to ensure that the results reflect field conditions in Bangladesh. Because farmers harvest rice after complete maturity and partial drying in the field, the germination test results can be inferred for the existing field conditions in Bangladesh. In total, 32 (28 coastal genotypes and 4 released varieties) genotypes were collected and evaluated for the germination test. The rice landraces used in this study are possibly the most popular and widely grown cultivars in the coastal area of Bangladesh [22]. The genotypes are generally tall, and the seed sizes and weight are largely variable. More details of the genotypes can be found in the paper by Mia et al. (2021) [22]. For the germination test, sand was collected, sieved, and thoroughly washed to remove impurities. A total of 128 plastic pots were cleaned, labeled, and filled with moistened sand up to the field capacity. Next, the sand was placed in a plastic pot, and water was added to moisten the sand properly up to the field capacity. The sand was then scrapped with a scraper to enhance aeration. For each genotype, 100 seeds were planted in 4 pots (25 seeds per pot) and kept moist to ensure proper germination. Then, water was sprayed to maintain the adequate moisture for germination. The plastic pots with seeds were then incubated in a growth chamber. Seeds were incubated at 25 °C with 95% relative humidity and a 12/12 h light–dark cycle for 14 days (Figure 1). The growth chamber was pre-calibrated to ensure appropriate growing conditions during germination test. After 14 days, the seedling was evaluated following the guidelines of ISTA (2006) [21]. The germination and dormancy percentage were calculated using the following formulas:

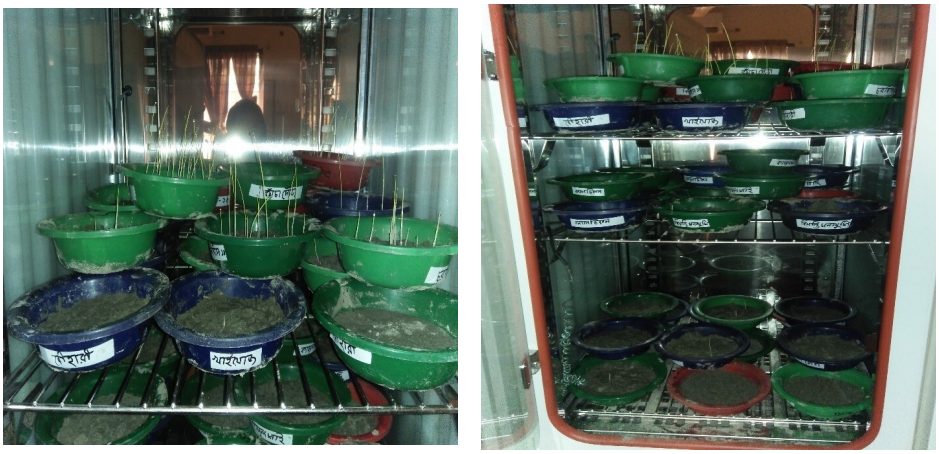
$$Germination\ (\%) = \frac{\text{Number of normal seedlings} \times 100}{\text{Number of seed set for germination test}} \quad (1)$$

$$Dormancy\ (\%) = \frac{\text{Number of fresh seed} \times 100}{\text{Number of seed set for germination test}} \quad (2)$$

Data Collection in Germination Test

Data were collected 14 days after seed setting. Sand was carefully removed to avoid root injury, and seeds and seedlings were gently washed with water. Then, the seeds were categorized as normal seedlings, abnormal seedlings, dormant seeds, dead seeds, and hard seeds, following the ISTA guidelines [21]. The roots and shoots of normal seedlings were measured, oven-dried at 105 °C for 48 h, and weighed to determine dry biomass. The

seedling-normalized biomass production was then calculated by dividing the respective biomass by the number of normal seedlings.



(**a**) (**b**)

Figure 1. Incubation of seeds for germination in the growth chamber for 14 days at 25 °C (12/12 light and dark period). Panels (**a**,**b**) both show the germination of seeds of different landraces in the growth chamber.

2.2. Electrical Conductivity Test

For determining the electrolyte leaching of seeds, the electrical conductivity (EC) test was used [18]. Briefly, the seeds of 32 genotypes were soaked in distilled water at a 1:20 (seed–water) ratio for 48 h. During soaking, the container was kept open, allowing for the easy exchange of gases in and out of the container to avoid the effects of elevated carbon dioxide on the seed respiration. Next, the suspension was filtered to remove unwanted particles, while the filtrate was used for the determination of the EC value using an EC meter (HI 215, Hanna, Woonsocket, RI, USA) [23].

2.3. Priming Experiment

To examine the priming effect, a germination test was conducted on 20 genotypes of seeds (listed in Table 1) after soaking seeds for 24 h. The selection of the genotype was based on the results of the previous germination test. Basically, genotypes with lower germinations were included since the focus of this study was to identify the dormant genotypes. For each genotype, 5 g of seeds were soaked in water for 24 h in separate beakers. The seeds were then subjected to the germination test described earlier.

Table 1. Selected genotypes for breaking dormancy using HNO_3 treatment.

1. Lalmota	*6. Lal chikon*	*11. Bari mota*	*16. Chinigura*
2. Bashful chikon	*7. Bashful*	*12. Birindi*	*17. Dudhkolom*
3. Lokkhima	*8. Motha mota*	*13. Sakorkhora*	*18. Kajalhai*
4. Calendar mota	*9. Dishari*	*14. Kalokhaiya*	*19. Nakuchimota*
5. Sada mota	*10. Kejrenjal*	*15. Tulsimala*	*20. BRRI dhan 41*

2.4. Breaking Seed Dormancy Using Nitric Acid

In this study, the concentration of HNO_3 was selected based on the recommendations of ISTA. Among the 32 genotypes, 20 genotypes (Table 1) were selected based on the low performance of the germination test (i.e., higher dormancy seeds). The selected seeds were treated with 1 N HNO_3 to break dormancy. Therefore, the experiment consisted of two factors, i.e., the (a) genotype and (b) HNO_3 treatment (with or without). The total number

of experimental units was 120 (2 treatments × 20 genotypes × 3 replications) since we replicated the treatments.

The 1 N HNO_3 was prepared from 65% HNO_3 according to the following formula:

$$Molarity\ of\ acid = \frac{\text{Percentage}(\%) \times Density\ of\ acid \times 10}{\text{Molar mass of acid}} \quad (3)$$

After the calculation of the molarity of the HNO_3, the acid was diluted to 1 N. The seeds of each genotype were soaked individually into a 1 N acid solution for 24 h, and then, the seeds were thoroughly washed into current water. Next, a germination test was conducted on the seed, as discussed in the previous section.

2.5. Statistical Analysis

One-way ANOVAs were performed for experiment one (32 genotypes in the germination test) and experiment two (20 genotypes in the priming experiment), while a two-way ANOVA was conducted for experiment three (two dormancy-breaking treatments with 20 genotypes). The means were separated using Tukey's HSD. Statistical analysis was carried out using JMP 8.0 software (v8.0.1, Cary, NC, USA), and the data were checked to determine whether they meet model assumptions of normality and equal variance. If the conditions were not met, the data were log-transformed.

3. Results

3.1. Germination Capacity of Different Cultivars

The germination percentage of the local rice varied significantly ($p < 0.01$, Table 2). The highest germination percentage was found in *Bina dhan 10* (72%). *Bari mota* (0%), *Chinigura* (0%), and *Tulsimala* (0%) did not germinate. Very low germination was found in *Dishari* (1%), *Birindi* (1%), *Lal chikon* (1%), *Bashful chikon* (1%), and *Sakhharkhora* (2%). However, the rate of germination of the majority of the genotypes was below 20%. Thus, the dormancy of these rice seeds was high just after harvesting. Since dormancy is opposite to germination, the most dormant seed was found in *Lal chikon* (96%), *Bashful* (97%), *Tulsimala* (100%), and *Chinigura* (99%), and the less dormant seed was found in *Bina dhan 10* (11%).

Table 2. Seed quality of different local rice landraces.

Genotype	Germination (%)	Shoot Weight per Seedling (mg)	Root Weight per Seedling (mg)	Total Biomass per Seedling (mg)	Dormancy (%)	EC Value (mS m^{-1})
Bina Dhan 10	72.0 ± 4.3^{a}	$7.50 \pm 0.07^{a–d}$	$5.12 \pm 0.49^{a–e}$	$12.69 \pm 1.12^{a–d}$	11.00 ± 5.00^{h}	$10.50 \pm 0.30^{i–k}$
BRRI Dhan 49	30.0 ± 2.6^{cd}	$5.90 \pm 0.01^{a–e}$	$5.13 \pm 0.83^{a–e}$	$11.05 \pm 0.91^{a–d}$	$60.00 \pm 2.31^{e–g}$	$19.00 \pm 0.40^{a–c}$
Bionti Monkhushi	$22.0 \pm 7.7^{c–f}$	$5.40 \pm 1.30^{a–e}$	$4.83 \pm 1.78^{a–e}$	$10.27 \pm 2.55^{a–e}$	$74.00 \pm 6.22^{a–f}$	10.30 ± 0.20^{jk}
Lal Mota	4.0 ± 1.6^{ef}	$3.60 \pm 1.50^{b–e}$	$2.78 \pm 1.57^{b–e}$	$6.47 \pm 3.06^{b–e}$	96.00 ± 1.63^{ab}	10.00 ± 0.40^{jk}
Bashful Chikon	1.0 ± 1.0^{f}	1.30 ± 1.30^{de}	0.17 ± 0.17^{e}	1.55 ± 1.55^{de}	97.00 ± 1.91^{ab}	$17.00 \pm 2.00^{a–d}$
Lokkhima	2.0 ± 1.2^{ef}	$3.30 \pm 2.10^{b–e}$	$1.07 \pm 0.66^{c–e}$	$4.45 \pm 2.81^{c–e}$	96.00 ± 1.63^{ab}	$11.50 \pm 0.30^{g–k}$
Calendar Mota	5.0 ± 5.0^{ef}	1.20 ± 1.20^{de}	$0.90 \pm 0.90^{c–e}$	2.08 ± 2.08^{de}	$90.00 \pm 8.72^{a–d}$	$12.00 \pm 0.04^{f–k}$
Sada Mota	5.0 ± 3.0^{ef}	1.80 ± 1.20^{de}	$0.99 \pm 0.65^{c–e}$	2.83 ± 1.64^{de}	$92.00 \pm 2.83^{a–d}$	$19.00 \pm 0.20^{b–f}$
Lal chikon	1.0 ± 1.9^{f}	0.60 ± 0.62^{de}	0.33 ± 0.33^{de}	0.95 ± 0.95^{de}	96.00 ± 2.83^{ab}	$14.50 \pm 0.60^{d–h}$
Bashful	3.0 ± 4.6^{ef}	1.80 ± 1.30^{de}	$1.10 \pm 0.75^{c–e}$	2.93 ± 2.00^{de}	$95.00 \pm 3.00^{a–c}$	$16.30 \pm 0.20^{b–e}$
Motha mota	$8.0 \pm 1.0^{d–f}$	$2.10 \pm 1.20^{c–e}$	$1.33 \pm 0.77^{c–e}$	$3.36 \pm 1.94^{c–e}$	$90.00 \pm 6.00^{a–d}$	$13.50 \pm 0.20^{d–j}$
Dishari	1.0 ± 4.7^{f}	0.80 ± 0.82^{de}	0.20 ± 0.20^{e}	1.03 ± 1.03^{de}	99.00 ± 1.00^{ab}	$15.00 \pm 0.40^{c–h}$
Kejrenjal	$7.0 \pm 0.0^{d–f}$	$2.20 \pm 1.41^{b–e}$	$3.16 \pm 2.37^{b–e}$	$5.33 \pm 3.77^{c–e}$	$86.00 \pm 4.76^{a–e}$	$10.50 \pm 0.60^{i–k}$
Bari mota	0.0 ± 0.0^{f}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	100.00 ± 0.00^{a}	$10.50 \pm 0.30^{i–k}$
Birindi	1.0 ± 1.2^{f}	$3.40 \pm 3.40^{b–e}$	$0.90 \pm 0.90^{c–e}$	$4.30 \pm 4.30^{c–e}$	99.00 ± 1.00^{ab}	$12.50 \pm 0.30^{e–j}$
Sakorkhora	2.0 ± 1.9^{ef}	$2.40 \pm 1.47^{b–e}$	$0.58 \pm 0.33^{c–e}$	2.98 ± 1.78^{de}	98.00 ± 1.15^{ab}	$16.00 \pm 0.40^{b–e}$
kalokhaiya	3.0 ± 0.0^{ef}	1.78 ± 1.10^{de}	$3.22 \pm 1.87^{b–e}$	$5.01 \pm 2.94^{c–e}$	$91.00 \pm 4.43^{a–d}$	$14.30 \pm 0.20^{d–i}$
Tulsimala	0.0 ± 0.0^{f}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	100.00 ± 0.00^{a}	20.50 ± 0.90^{a}
Kacha Mota	$24.0 \pm 1.9^{c–f}$	$6.30 \pm 1.10^{a–e}$	$5.33 \pm 1.45^{a–e}$	$11.64 \pm 2.34^{a–e}$	$73.00 \pm 5.74^{b–f}$	$15.50 \pm 0.20^{c–f}$
Jaini	$17.0 \pm 6.8^{c–f}$	$4.10 \pm 1.19^{b–e}$	$3.75 \pm 1.56^{b–e}$	$7.84 \pm 2.72^{a–e}$	$76.00 \pm 5.66^{a–f}$	20.30 ± 0.50^{a}

Table 2. *Cont.*

Genotype	Germination (%)	Shoot Weight per Seedling (mg)	Root Weight per Seedling (mg)	Total Biomass per Seedling (mg)	Dormancy (%)	EC Value (mS m^{-1})
Chinigura	0.0 ± 0.0 ^{f}	0.00 ± 0.00 ^{e}	0.00 ± 0.00 ^{e}	0.00 ± 0.00 ^{de}	99.00 ± 1.00 ^{ab}	15.30 ± 0.20 $^{c–g}$
Dudhkolom	9.0 ± 2.5 $^{d–f}$	11.50 ± 2.39 ^{a}	7.19 ± 3.04 $^{a–d}$	18.74 ± 5.03 ^{a}	89.00 ± 1.91 $^{a–d}$	19.50 ± 0.90 ^{ab}
Halde Mota	26.0 ± 5.3 $^{c–e}$	9.15 ± 2.20 $^{a–c}$	10.76 ± 2.55 ^{a}	19.92 ± 3.87 ^{a}	69.00 ± 4.73 $^{c–f}$	15.30 ± 1.00 $^{c–g}$
Kajol shai	4.0 ± 1.6 ^{ef}	2.67 ± 0.90 $^{b–e}$	1.78 ± 0.87 $^{b–e}$	4.46 ± 1.60 $^{c–e}$	96.00 ± 1.63 ^{ab}	14.50 ± 1.60 $^{d–h}$
Nakuchi Mota	3.0 ± 1.0 ^{ef}	2.90 ± 1.20 $^{b–e}$	0.80 ± 0.28 $^{c–e}$	3.70 ± 1.46 $^{c–e}$	97.00 ± 1.00 ^{ab}	8.50 ± 0.30 ^{k}
Nona Bokra	66.0 ± 5.7 ^{a}	5.76 ± 0.50 $^{a–e}$	5.25 ± 0.78 $^{a–e}$	11.02 ± 1.04 $^{a–e}$	16.00 ± 4.32 ^{h}	15.80 ± 0.60 $^{b–f}$
BRRI Dhan 41	9.0 ± 1.9 $^{d–f}$	3.76 ± 1.10 $^{b–e}$	2.67 ± 0.57 $^{b–e}$	6.43 ± 1.44 $^{b–e}$	88.00 ± 3.65 $^{a–d}$	16.80 ± 0.50 $^{a–d}$
Bouhari	30.0 ± 8.9 ^{cd}	4.04 ± 0.60 $^{b–e}$	3.82 ± 0.78 $^{a–e}$	7.86 ± 1.29 $^{a–e}$	67.00 ± 10.25 $^{d–f}$	10.00 ± 0.40 ^{jk}
Khaiyoj	13.0 ± 3.41 $^{d–f}$	5.95 ± 1.00 $^{a–e}$	4.45 ± 1.62 $^{a–e}$	10.40 ± 2.50 $^{a–e}$	85.00 ± 1.91 $^{a–e}$	12.50 ± 0.90 $^{e–j}$
Bina Dhan 8	68.0 ± 8.0 ^{ab}	8.20 ± 0.00 $^{a–e}$	8.71 ± 1.03 $^{a–c}$	16.91 ± 1.05 $^{a–c}$	24.00 ± 7.30 ^{gh}	15.20 ± 0.70 ^{k}
Charbindi	55.3 ± 7.7 ^{ab}	8.80 ± 1.74 ^{ab}	8.10 ± 1.48 ^{ab}	16.97 ± 2.23 ^{ab}	35.00 ± 8.39 ^{gh}	11.70 ± 1.00 $^{h–k}$
Kalijira	40.0 ± 9.7 ^{bc}	4.45 ± 0.40 $^{a–e}$	6.77 ± 2.29 $^{a–e}$	11.23 ± 2.58 $^{a–e}$	52.00 ± 9.52 ^{fg}	15.00 ± 0.80 $^{d–h}$
p value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Level of significance	**	**	**	**	**	**

** = significant at 1% level of probability. Means followed by the same letter (a–k) in a column do not differ significantly ($p < 0.05$) based on statistical test.

3.2. Biomass Production of Seedlings

The biomass production of seedlings indicates the rate of germination, which has significant implications for seed quality deterioration. Genotype had a significant effect ($p < 0.01$, Table 2) on the seedling-normalized shoot weight. A significantly higher shoot weight was found in *Dudhkolom* (11.5 mg) than in *Bari Mota* (0 mg). Similarly, there were significant variations in the seedling-normalized root weight of genotypes. The highest average root weight was found in *Halde Mota* (10.76 mg), and the lowest was found in *Bari Mota* (0 mg). Therefore, the normalized total seedling weight varied significantly for varieties ($p < 0.01$, Table 2). Specifically, a significantly higher biomass production was recorded in *Dhudhkolom* (18.74 mg) and *Holde Mota* (19.92 mg) than in *Dishari* and *Balshul chikon*.

3.3. Electrical Conductivity (EC)

The analysis of variance revealed that the EC values varied significantly within the varieties ($p < 0.01$, Table 2). The highest EC value was found in *Tulsimala* (20.50 mS m^{-1}), and the lowest was found in *Nakuchimota* (8.50 mS m^{-1}).

3.4. Priming Effect

Priming had a significant effect on seed germination ($p < 0.05$, Table 3). The average germination across all cultivars was 46.3% in the priming treatment, while it was only 3.4% when the seed was not primed. The germination capacity of different varieties also varied significantly with or without priming treatments ($p < 0.01$). For the average across priming treatments, higher germination was recorded in *BRRI dhan* 41 (47.15%), *Motha mota* (46%), *Kejrenjal* (40.15%), *Sadamota* (39.8%), and *Dudhkolom* (39.15%), while it was low in *Chinigura* (5.63), *Barimota* (4.7%), and *Sakhorkora* (1%). The interactive effects of priming and cultivars were also significant since varieties performed differently when set for germination with or without priming. The maximum germination was recorded in *BRRI dhan 41* (85.3%), *Motha mota* (84%), *Lal chikon* (74.6%), *Sadamota* (74.6%), and *Bashful* (53.3%) when their seeds were primed. Even though the seeds were primed for 24 h, the germination of *Nakuchimota*, *Kalokhaiya*, *Lokhhima*, *Chinigura*, *Tulsimala*, *Bari mota*, and *Sakhorkora* was less than 15%.

Table 3. Priming effects of seeds on germination.

Cultivar	Priming	Germination (%)
BARI mota	No	0.0 ± 0.0^{h}
	Yes	9.33 ± 0.9
Bashful	No	3.0 ± 1.9^{gh}
	Yes	53.3 ± 2.4^{cd}
Bashful chikon	No	1.0 ± 1.0^{h}
	Yes	73.3 ± 2.4^{ab}
Birindi	No	1.0 ± 1.0^{h}
	Yes	37.3 ± 2.4^{ef}
BRRI dhan 41	No	9.0 ± 1.9^{gh}
	Yes	85.3 ± 0.9^{a}
Calender mota	No	5.0 ± 5.0^{gh}
	Yes	45.3 ± 4.1^{de}
Chinigura	No	0.0 ± 0.0^{h}
	Yes	10.6 ± 0.9
Dishari	No	1.0 ± 1.0^{h}
	Yes	69.3 ± 1.8^{b}
Dudh kolom	No	9.0 ± 2.5^{gh}
	Yes	69.3 ± 2.4^{b}
kajolshai	No	4.0 ± 1.6^{gh}
	Yes	65.3 ± 0.9^{bc}
Kalokhaiya	No	3.0 ± 1.9^{gh}
	Yes	14.6 ± 0.9^{g}
Kejrenjal	No	7.0 ± 4.7^{gh}
	Yes	73.3 ± 1.8^{ab}
Lal chikon	No	1.0 ± 1.0^{h}
	Yes	74.6 ± 2.4^{ab}
Lal mota	No	4.0 ± 1.6^{gh}
	Yes	33.3 ± 1.8^{ef}
Lokkhima	No	2.0 ± 1.1^{h}
	Yes	10.6 ± 0.9
Motha mota	No	8.0 ± 4.6^{gh}
	Yes	84.0 ± 1.6^{a}
Nakuchimota	No	3.0 ± 1.0^{h}
	Yes	32.0 ± 3.2^{f}
Sadamota	No	5.0 ± 3^{gh}
	Yes	74.6 ± 1.8^{ab}
Sakorkhora	No	2.0 ± 1.1^{h}
	Yes	0.0 ± 0.0^{h}
Tulsimala	No	0.0 ± 0.0^{h}
	Yes	10.6 ± 1.8^{gh}

Means followed by the same letter (a–h) in a column do not differ significantly ($p < 0.05$) based on statistical test.

3.5. Seed Treatment with HNO_3

For the average across varieties, acid treatment significantly ($p < 0.01$, Table 4) reduced the germination of rice. The germination was 44% in the control treatment and only 2% in the acid-treated seeds (Table 4). Across acid treatments, genotypes differed significantly regarding normal seedlings, dead seeds, and thus germination. The highest number of normal seedlings was found in *Chinigura* (4), and the lowest was found in *Sakorkhora* (0). The highest number of dormant seeds was found in *Sakorkhora* (25), and the lowest was found in *Chinigura* (21). There was a significant interaction between the acid treatment and variety ($p < 0.01$). The highest number of normal seedlings was found in *Mothamota* (21) and *BRRI dhan 41* (21) in the control condition (H0), and the lowest were found in *Barimota* (1.67) and *Sakorkhora* (0). The highest number of normal seedlings was found in *Nakuchimota* (4) and Chinigura (4) in HNO_3 treatment (H1), and the lowest was found in *Sadamota* (0), *Bashful chikon* (0), etc. The highest number of dormant seeds was found in *Sakorkhora* (25) in the control condition (H0), and the lowest were found in *Mothamota* (4) and *BRRI dhan 41* (3.67). The highest number of normal seedlings was found in *Chinigura* (4) in HNO_3 treatment (H1), and the lowest was found in *BRRI dhan 41* (0) and *Sakorkhora* (0). The highest germination percentage was found in *Mothamota* (84%) and *BRRI dhan 41* (84%) in

the control condition (H0), and the lowest were found in *Barimota* (6.67%) and *Sakorkhora* (0%). The highest germination percentage was found in *Nakuchimota* (16%) and *Chinigura* (16%) in HNO_3 treatment (H1), and the lowest was found in *Sadamota* (0%) and *Bashful chikon* (0%).

Table 4. Effect of genotype and acid treatment interaction on normal seedlings, dormant seeds, and germination percentage.

Genotype	Treatment	Number of Normal Seedling per Seeds	Number of Dormant Seed per 25 Seeds	Germination Percentage
Lal Mota	H0	8 ± 0.57^{ef}	16.7 ± 0.7^{d}	32 ± 2.3^{ef}
	H1	0.33 ± 0.33^{i}	24.7 ± 0.3^{a}	1.3 ± 1.3^{i}
bashful Chikon	H0	17.33 ± 0.88^{b}	6.7 ± 0.9^{gh}	69.3 ± 3.5^{b}
	H1	0.0 ± 0.0^{i}	24.7 ± 0.3^{a}	0.0 ± 0.0^{i}
Lokkhima	H0	2 ± 0.57^{hi}	$22.3 \pm 0.3^{a–c}$	8.0 ± 2.3^{hi}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
calender Mota	H0	10.33 ± 0.88^{de}	13.7 ± 1.5^{de}	41.3 ± 3.5^{de}
	H1	0.0 ± 0.0^{i}	24.3 ± 0.3^{ab}	0.0 ± 0.0^{i}
Sada Mota	H0	18 ± 0.57^{ab}	6.3 ± 0.7^{gh}	72.0 ± 2.3^{ab}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Lal chikon	H0	18 ± 1.2^{ab}	6.3 ± 0.9^{gh}	72.0 ± 4.6^{ab}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Bashful	H0	13.0 ± 0.6^{cd}	11.7 ± 0.8^{ef}	52.0 ± 2.3^{cd}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Motha mota	H0	21.0 ± 0.6^{a}	4.0 ± 0.6^{h}	84.0 ± 2.3^{a}
	H1	0.3 ± 0.3^{i}	24.7 ± 0.3^{a}	1.3 ± 1.3^{i}
Dishari	H0	17.0 ± 0.6^{b}	7.7 ± 0.7^{g}	68.0 ± 2.3^{b}
	H1	0.7 ± 0.3^{i}	24.3 ± 0.3^{ab}	2.7 ± 1.3^{i}
Kejrenjal	H0	18.0 ± 0.6^{ab}	6.7 ± 0.6^{gh}	72.0 ± 2.3^{ab}
	H1	0.3 ± 0.3^{i}	24.7 ± 0.3^{a}	1.3 ± 1.3^{i}
Bari mota	H0	1.7 ± 0.3^{hi}	$22.7 \pm 0.3^{a–c}$	6.6 ± 1.3^{hi}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Birindi	H0	9.0 ± 0.6^{ef}	15.7 ± 0.9^{d}	36.0 ± 2.3^{ef}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Sakorkhora	H0	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.0^{a}	0.0 ± 0.0^{i}
Kalokhaiya	H0	3.0 ± 0.6^{hi}	21.3 ± 0.3^{bc}	12.0 ± 2.3^{hi}
	H1	1.7 ± 0.3^{hi}	$23.3 \pm 0.3^{a–c}$	6.7 ± 1.3^{hi}
Tulsimala	H0	2.3 ± 0.9^{hi}	$22.3 \pm 0.7^{a–c}$	9.3 ± 3.5^{hi}
	H1	0.7 ± 0.3^{i}	24.3 ± 0.3^{ab}	2.7 ± 1.3^{i}
Chinigura	H0	2.0 ± 0.6^{hi}	$22.3 \pm 0.6^{a–c}$	8.0 ± 2.3^{hi}
	H1	4.0 ± 0.6^{gh}	21.0 ± 0.9^{c}	16.0 ± 2.3^{gh}
Dudhkolom	H0	17.0 ± 0.6^{b}	7.7 ± 0.3^{g}	68.0 ± 2.3^{b}
	H1	0.3 ± 0.3^{i}	24.7 ± 0.3^{a}	1.3 ± 1.3^{i}
Kajalhai	H0	16.0 ± 0.6^{bc}	8.7 ± 0.0^{fg}	64.0 ± 2.3^{bc}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.9^{a}	0.0 ± 0.0^{i}
Nakuchimota	H0	7.0 ± 0.6^{i}	16.7 ± 1.5^{c}	28.0 ± 2.3^{fg}
	H1	4.0 ± 1.5^{gh}	21.0 ± 0.3^{d}	16.0 ± 6.1^{gh}
BRRI dhan 41	H0	21.0 ± 0.6^{a}	3.7 ± 0.0^{h}	84.0 ± 2.3^{a}
	H1	0.0 ± 0.0^{i}	25.0 ± 0.3^{a}	0.0 ± 0.0^{i}
F value		<0.01	<0.01	<0.01
Level of Significance		**	**	**

** = significant at 1% level of probability. Means followed by the same letter (a–i) in a column do not differ significantly ($p < 0.05$) based on statistical test.

4. Discussion

4.1. Variable Seed Dormancy in Local Rice Landraces

Germination is a desirable trait for a crop, while germination in the field may cause a serious loss to farmers since germinated seeds can be used as food. The pre-harvest sprouting of mature rice grains is a major problem in agricultural production, especially in humid and coastal regions. Besides yield loss, PHS also alters and decreases the grain's nutritional content and processing quality and, finally, negatively influences industrial processing [24]. In this study, we found a significant difference in the germination capacity, seedling biomass production, and electrolyte leakage among the freshly harvested seeds of 32 Aman rice genotypes (28 landraces and 4 released varieties—*BINA dhan 8*, *BINA dhan 10*, *BRRI dhan 41*, and *BRRI dhan 49*). Among all cultivars, only ten genotypes had a germination capacity of over 20%. These cultivars were *BINA dhan 10 & 8*, *Nakuchimota*, *Charbindi*, *Kalizera*, *BRRI dhan 49*, *Bouhori*, *Holde mota*, *Kachamota*, and *Bionti monshushi*. The dormancy was higher in *Bari mota* (100.0 ± 0.0%), *Tulsimala* (100.0 ± 0.0%), *Chinigura* (99.0 ± 1.0%), *Dishari* (99.0 ± 1.0%), *Birindi* (99.0 ± 1.0%), *Sakharkhora* (98.0 ± 1.2%), and *Nakuchimota* (97.0 ± 1.0%), suggesting a clear variability in local landraces in their dormancy. A similarly higher dormancy has been reported in wild rice and its sister [17,25,26]. The dormancy of rice seed is linked to many physiological activities (i.e., enzymes, hormones, or other phytochemical activity of grains), while it is also suggested that the dormancy is associated with starch content and its quality [27,28]. However, the physiological activities of seed dormancy are also controlled through its genetic constituent [9]. In this study, the underlying mechanisms controlling dormancy were not studied. Nevertheless, these results indicate that many local Aman landraces carry seed dormancy, which is a good characteristic of rice for cultivating in the coastal area of Bangladesh. Specifically, the identified genotypes can be preferentially cultivated in this area to avoid yield loss, and these genotypes can potentially be used in a future breeding program.

Seedling biomass can provide important information about the rate of germination and thus the rate of seed sprouting during the pre-harvesting stage. In our study, the largest seedling biomass was found in *BINA dhan 8*, *Bina dhan 10*, and *Charbindi*. These varieties also had a higher rate of germination. The biomass production per seedling was higher for some local rice (such as *Holde mota* and *Dudh kolom*), suggesting that their rate of seedling growth was high. This implies that a higher biomass production of seedlings during germination would quickly use up the reserved food that would deteriorate seed quality quickly, and it would also be difficult to thresh grains from panicles. In contrast, this carries positive implications for crop production since a higher biomass production indicates highly vigorous seeds, but just after maturity.

The seed priming of rice seeds with distilled water for 24 h accelerated germination (Table 4), as previously reported for other crops, such as maize, sorghum, pearl millet, finger millet, cotton, beans, and maize [29–31]. Compared to non-priming, a significant improvement of germination was recorded in *BRRI dhan 41* (85.3% vs. 9%), *Motha mota* (84% vs. 8%), *Lal chikon* (74.6% vs. 1%), *Sadamota* (74.6% vs. 5%), and *Bashful* (53.3% vs. 3%). This increment in germination can be attributed to the pre-mobilization of seed reserves during the priming period [12,32,33], leaching of germination inhibitors into the priming solution, hydrolysis of ABA [34], and preorganization of membrane structures [35]. The variable effects of priming on the germination test in different genotypes might be associated with seed characteristics.

Seed vigor, examined by measuring the electrical conductivity, showed that there was significant variability in the genotypes in seed vigor. However, this seed vigorousness did not directly translate into germination (the relationship between the EC values and germination rate was not significant) since many of the genotypes had significant seed

dormancy. Moreover, it was also not clear whether there was genetic variability in terms of membrane permeability to release metabolites of the seeds, which may be an interesting topic for future research.

4.2. Pre-Treatments of Rice Seeds with Nitric Acid-Breaking Seed Dormancy

Seed dormancy, defined as the failure of a viable seed to germinate under favorable environmental conditions, can be classified into several types: physical (seed coat restricting water and gas exchange), physiological (biochemical blocks to embryo growth), morphological (underdeveloped embryos), and morphophysiological (a combination of these types) [36–40]. Dormancy-breaking treatments are selected based on the type of dormancy, with commonly used methods including mechanical and chemical scarification, such as acid treatments and water soaking [36–40]. Nitric acid, in particular, may break dormancy by chemically modifying the seed coat, enhancing water imbibition and gas exchange, reducing germination-inhibiting hormones, and potentially generating reactive nitrogen (RNS) and oxygen species (ROS). These processes are thought to modulate hormonal pathways by decreasing abscisic acid (ABA) and increasing gibberellin (GA) activity, although the exact mechanisms remain unclear [12,41,42].

The proposed concentration of nitric acid (1 N) by ISTA inhibited the germination of all tested cultivars compared to the control (Table 4). We believe that this occurred due to the damage of the embryo with this concentration, which require further investigation to identify an optimum concentration for indigenous rice. In fact, similar findings were reported by Mutinda et al. [43], who observed that the treatment of rice seeds with higher concentrations of nitric acid inhibited germination, while the low concentration of nitric acid promoted germination. However, the germination of *Chinigura* was doubled with dormancy-breaking treatment with 1 N HNO_3, suggesting that both positive and negative effects were observed. Waheed et al. [40] and Naredo et al. [44] reported that nitric acid promoted seed germination in both wild and cultivated rice species. They noted that the different concentrations used had variable responses among the varieties.

In the present study, the degree of dormancy varied depending on the rice variety. *Chinigura* and *Nakuchimota* had weaker dormancy compared to other cultivars, as indicated by higher germination percentages with 1 N HNO_3 treatment. In rice, dormancy may be due to an impermeable seed coat or factors related to the embryo [45,46]. Moreover, early or late harvesting affects seed maturity, consequently affecting germination and dormancy [47,48]. We did not study the molecular mechanisms responsible for rice seed dormancy here and acknowledge this as a limitation of the study [14,49].

The contradictory effects of nitric acid treatment on different genotypes may stem from genetic variations in seed coat structure, dormancy intensity, or chemical sensitivity. For instance, thicker seed coats or higher levels of dormancy-inducing compounds in certain genotypes may require varied treatment intensities, emphasizing the need for studies on genotype differences to optimize treatment protocols.

5. Conclusions

Seed germination is a crucial process that influences crop yield and quality, while germination during harvesting may affect the grain quality. An experiment was conducted to evaluate the germination performance of 28 local rice genotypes at harvest. In a separate experiment, true dormancy was assessed by applying a dormancy-breaking treatment to the genotypes that remained dormant in the initial experiment. From the first experiment, the seeds of 12 high germinating genotypes were found from 28 local rice genotypes. In contrast to our expectation, dormancy treatment did not improve germination; except for in *Chinigura*, the seeds of many local genotypes were sensitive to acid treatments. However,

our results show that *Bari Mota*, *Chinigura*, *Tulsimala*, *Sakhararkhura*, *Khalokhaiya*, *Lokhhimota*, and *Nakuchimota* carry dormancy that can potentially be cultivated in the coastal area since they have strong dormancy just after harvesting. Altogether, this study is the first to report climate-resilient local landraces for the coastal area. Specifically, the identified genotypes with enhanced seed dormancy can be strategically cultivated in coastal regions to mitigate yield losses caused by pre-harvest sprouting. These genotypes not only offer immediate benefits for stabilizing production in these vulnerable areas but also hold significant potential for future breeding programs. Moreover, our research provides some indications for future research, which includes understanding molecular and physiological mechanisms for the observed dormancy.

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