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Effects of Hydropriming and Post-Priming Storage Duration on Germination, Emergence, and Early Growth of Cram 6 Rice (*Oryza sativa* L.)

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Abstract **Original Research Article**

Rice (*Oryza sativa* L.) is one of the world's most important food crops and plays a key role in food security across Africa. Improving seed physiological quality is essential for enhancing crop establishment and early plant development. This study evaluated the effects of hydropriming and post-priming seed storage duration on the germination, emergence, and growth of CRAM 6 rice. The experiments were conducted from January to October 2025 at the experimental station of the University of Man, Côte d'Ivoire. Besides the control treatment (non-primed seeds), hydroprimed seeds were stored for zero (W0), one (W1), two (W2), three (W3), and four (W4) weeks before sowing. Germination tests were carried out in Petri dishes using a completely randomized design with four replications, while emergence and growth experiments were conducted under greenhouse conditions. Data were analyzed using the Kruskal–Wallis test followed by Dunn–Holm's post hoc test at the 5% significance level. Hydropriming significantly improved seed performance when seeds were sown immediately after treatment. The W0 treatment showed the shortest germination onset time (12 h), the highest germination percentage (98.61%), and the highest emergence percentage (92.67%). It also produced the most vigorous plants, with a mean height of 75.50 cm and a total dry biomass of 12.35 g. Conversely, increasing storage duration after hydropriming progressively reduced germination, emergence, and plant growth, while increasing seed infection. These findings demonstrate that hydropriming is an effective technique for improving the establishment and early growth of CRAM 6 rice, provided that seeds are sown shortly after treatment.
Keywords: *Oryza sativa*, hydropriming, seed storage, germination, emergence, growth.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most widely cultivated cereal crops worldwide and serves as the staple food for more than half of the global population (Jarin *et al*., 2024). In sub-Saharan Africa, particularly in Côte d'Ivoire, rice plays a crucial role in food security and socio-economic development. Sustainable improvement of rice production depends not only on the use of high-performing varieties but also on rapid and uniform crop establishment, which is essential for achieving optimal yield potential (Farooq *et al*., 2009).

Seed physiological quality is a key factor influencing successful crop establishment. Rapid and uniform germination promotes better seedling emergence and vigorous early growth, whereas poor seed vigor may impair plant establishment and ultimately reduce crop productivity (Paparella *et al*., 2015). Consequently, several seed enhancement techniques have been developed to improve seed physiological performance. Among these techniques, seed priming has been widely recognized as an effective approach for enhancing seed quality. Priming consists of partially hydrating seeds to initiate the metabolic processes associated with germination without allowing radicle protrusion, followed by drying before sowing (Corbineau *et al*., 2023). Various priming methods have been developed, including osmopriming, chemopriming, hormopriming, and hydropriming. Hydropriming, which relies solely on water as the priming agent, is particularly attractive because it is simple, inexpensive, and easily adopted by farmers (Varier *et al*., 2010).

Numerous studies have demonstrated that hydropriming improves germination performance and seedling vigor in a wide range of crop species. In rice, hydropriming has been reported to accelerate germination, enhance seedling emergence, and promote early plant growth (Nakao *et al*., 2020; Sakagami *et al*., 2024). These beneficial effects are generally attributed to the early activation of metabolic processes involved in reserve mobilization and embryo development. Despite its advantages, one of the major challenges associated with hydropriming is the storage of primed seeds. Several studies have reported a gradual decline in the longevity of primed seeds during storage, resulting in a reduction of the benefits initially gained from the treatment (Varier *et al., 2010*; Hussain *et al*., 2015; Wang *et al*., 2018). In contrast, Bore *et al.,*(2023) showed that certain rice varieties, such as NERICA 4, can maintain higher vigor than non-primed seeds for several months when stored under favorable conditions. These findings indicate that the effects of post-priming storage are influenced by genotype, storage duration, and storage conditions.

Despite the growing body of research on hydropriming, little information is available on how post-priming storage duration affects the successive stages of rice establishment, particularly in varieties cultivated in Côte d'Ivoire. Furthermore, no information is currently available on the response of the CRAM 6 rice variety to this technique. Therefore, the present study was undertaken to evaluate the effects of hydropriming and different post-priming storage durations on the germination, emergence, and growth of CRAM 6 rice. The specific objective was to assess the effects of post-priming storage duration on germination performance, seedling emergence, and early growth of CRAM 6 rice.

2. MATERIALS AND METHODS

2.1. Study site and experimental period

The study was conducted from January to October 2025 at the experimental station of the University of Man, located in western Côte d'Ivoire. Germination tests were carried out under laboratory conditions, whereas seedling emergence and growth experiments were conducted in a greenhouse. To ensure the reproducibility of the results, all experiments were repeated twice, with a two-month interval between the two experimental runs.

2.2. Plant material

The plant material consisted of rice (*Oryza sativa* L., Poaceae) seeds of the CRAM 6 variety. The seeds were obtained from a harvest conducted in December 2024 at the National Center for Agronomic Research (CNRA) in Man, Côte d'Ivoire. Before the experiments, seeds were manually sorted to remove empty, damaged, or morphologically abnormal grains.

2.3. Hydropriming and seed storage

A preliminary study was conducted to determine the germination time of the CRAM 6 variety. The first radicle emergence was observed after 36 h of imbibition. Therefore, the hydropriming duration was set at 30 h to prevent germination during treatment. Hydropriming was performed by incubating the seeds on filter paper moistened with distilled water for 30 h at room temperature. After priming, the seeds were rinsed and dried under ambient conditions (25-30 °C and 60-80% relative humidity). They were then stored in jars under the same environmental conditions for different durations before sowing. Six treatments were considered: non-primed seeds (Control), hydroprimed seeds sown immediately after drying (W0), and hydroprimed seeds stored for one (W1), two (W2), three (W3), or four weeks (W4) before sowing.

2.4. *In vitro* germination assessment

Germination tests were conducted in the laboratory using Petri dishes arranged in a completely randomized design with six treatments corresponding to the different seed storage durations: non-primed seeds (Control), hydroprimed seeds sown immediately after treatment (W0), and hydroprimed seeds stored for one (W1), two (W2), three (W3), or four weeks (W4). Each treatment was replicated four times. For each replicate, thirty seeds were placed in a Petri dish containing three layers of filter paper. Each dish received 6.5 mL of distilled water, corresponding to the maximum water-holding capacity of the substrate. The dishes were maintained in darkness at room temperature. Observations were made every 12 h, and germinated seeds were counted and removed after each observation. A seed was considered germinated when the radicle reached a minimum length of 2 mm.

The parameters evaluated were germination onset time, final germination time, germination percentage (1), mean germination time (2), germination rate index (3), and percentage of infected seeds (4).

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds sown}} \times 100 \qquad (1)$$

$$\text{Mean germination time (h)} = \frac{\sum n_i \times t_i}{\sum n_i} \text{ (Nakao } et\ al., \text{2020)} \qquad (2)$$

$$\text{Germination rate index (seed h}^{-1}) = \frac{n_1}{t_1} + \frac{n_2}{t_2} + \cdots + \frac{n_i}{t_i} \text{ (Shahba } et\ al. \text{(2008)} \qquad (3)$$

where n_i is the number of seeds germinated at time t_i

$$\text{Percentage of infected seeds (\%)} = \frac{\text{Number of infected seeds}}{\text{Number of seeds sown}} \times 100 \qquad (4)$$

2.5. Evaluation of seedling emergence and plant growth under greenhouse conditions

2.5.1. Experimental design and crop management

The experiment was conducted in a greenhouse at the University of Man using a completely randomized design comprising six treatments corresponding to the different seed storage durations: non-primed seeds (Control), hydroprimed seeds sown immediately after treatment (W0), and hydroprimed seeds stored for one (W1), two (W2), three (W3), and four weeks (W4). Each treatment was replicated three times. A total of 90 plastic pots (3,800 cm^3), each containing approximately 5 kg of dry soil, were used. Before sowing, 2.5 g of NPK fertilizer (10–15–15) was incorporated into each pot. Five seeds were then sown per pot at a depth of approximately 3 cm. Pots were watered regularly to maintain favorable conditions for germination, seedling emergence, and plant growth. Twenty-two days after sowing, seedlings were thinned to reduce plant density. This operation was followed by the application of 2.5 g of urea per pot. A second application of NPK fertilizer (10–15–15) was carried out two months after sowing.

2.5.2. Emergence parameters

Seedling emergence was monitored daily until the number of emerged seedlings stabilized. The parameters evaluated were emergence onset time, final emergence time, emergence percentage, mean emergence time, and emergence rate index. These parameters were calculated using the same equations as those employed for germination, replacing the number of germinated seeds with the number of emerged seedlings.

2.5.3. Growth Parameters

Plant growth was assessed 70 days after sowing. Three plants were sampled per treatment and replicate, resulting in a total of 72 plants. After uprooting, the roots were carefully washed with water to remove adhering soil particles.

The parameters measured were plant height, number of leaves, number of tillers, root length, root volume, shoot dry biomass, and root dry biomass. Plant height and root length were measured using a measuring tape. Root volume was determined using the water displacement method in a graduated cylinder. Following the measurement of morphological traits, shoots and roots were separated and oven-dried at 60 °C for 72 h until constant weight was achieved. The samples were then weighed using a precision electronic balance to determine shoot dry biomass and root dry biomass, respectively.

2.6. Statistical Analysis

The collected data were entered into Microsoft Excel 2013 and analyzed using R software (R Core Team, 2025) through the Positron interface. Prior to statistical analyses, percentage data were subjected to angular transformation using the formula $arsin\sqrt{p} \times 180/\pi$, where p represents the proportion value of the parameter under consideration. However, the means presented in the tables and figures correspond to the original, non-transformed values. Differences among treatments were assessed using the non-parametric Kruskal-Wallis test. When significant differences were detected, multiple comparisons were performed using Dunn's post hoc test with Holm's adjustment at the 5% significance level.

3. RESULTS

3.1. Effects of hydropriming and seed storage duration on *in vitro* germination of rice

The Kruskal-Wallis test revealed a highly significant effect of seed storage duration on germination onset time, final germination time, mean germination time, and germination rate index (Table 1). For germination onset time, hydroprimed seeds sown immediately after treatment (W0) exhibited the lowest value (12 h). By comparison, the longest germination onset time was observed in W3 (40 h), whereas the Control, W1, W2, and W4 treatments showed statistically similar values ranging from 36 to 40 h. Likewise, final germination time was significantly affected by seed storage duration. The shortest final germination time was recorded in W0 (50 h). All other treatments exhibited significantly higher values, ranging from 109 to 137 h, with no statistical differences among them. Mean germination time ranged from 23.51 to 64.65 h depending on the treatment. The lowest value was obtained in W0 (23.51 h), while W4 recorded the highest value (64.65 h). The Control treatment showed an intermediate response, whereas W1, W2, W3, and W4 did not differ significantly from one another. A progressive decline in germination rate index was observed as post-hydropriming storage duration increased. The highest value was obtained in W0 (1.45 seeds h^{-1}), followed by the Control treatment (0.58 seeds h^{-1}). Intermediate values were recorded in W1 and W2, whereas W3 and W4 exhibited the lowest indices, with values of 0.33 and 0.31 seeds h^{-1}, respectively (Table 1). The same pattern was observed for germination percentage. Hydroprimed seeds sown immediately after treatment (W0) achieved the highest germination percentage (98.61%). Conversely, germination percentage declined with increasing storage duration after hydropriming, reaching its lowest values in W3 (63.89%) and W4 (57.78%). The Control, W1, and W2 treatments displayed intermediate responses (Figure 1).

Table 1. Effects of hydropriming and post-priming storage duration on germination parameters of CRAM 6 rice seeds.

Storage duration	Germination onset time (h)	Final germination time (h)	Mean Germination Time (h)	Germination rate index ($seed.h^{-1}$)
Control	36,00 ± 0,00 ^{b}	137,00 ± 49,73 ^{b}	23.51 ± 2.56 ^{a}	0,58 ± 0,06 ^{b}
W0	12,00 ± 0,00 ^{a}	50,00 ± 16,05 ^{a}	54.92 ± 6.25 ^{b}	1,45 ± 0,16 ^{a}
W1	36,00 ± 8,86 ^{b}	109,00 ± 10,80 ^{b}	60.44 ± 9.66 ^{b}	0,41 ± 0,14 ^{c}
W2	36,00 ± 0,00 ^{b}	121,00 ± 40,76 ^{b}	61.70 ± 6.67 ^{b}	0,43 ± 0,04 ^{c}
W3	40,00 ± 5,91 ^{b}	123,00 ± 38,33 ^{b}	62.25 ± 7.86 ^{b}	0,33 ± 0,08 ^{d}
W4	36,00 ± 0,00 ^{b}	115,00 ± 40,11 ^{b}	64.65 ± 6.90 ^{b}	0,31 ± 0,06 ^{d}
p	< 0,001	< 0,001	< 0,001	< 0,001

Values within a column followed by the same letter are not significantly different at the 5% level according to Dunn-Holm's multiple comparison test. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3, and W4: hydroprimed seeds stored for 1, 2, 3, and 4 weeks, respectively.

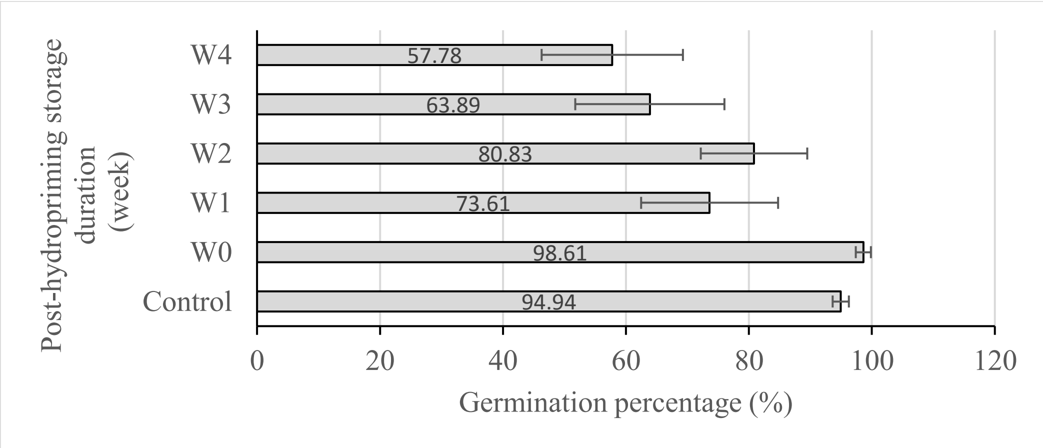

Figure 1: Effect of post-hydropriming storage duration on germination percentage of CRAM 6 rice seeds. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3 and W4: hydroprimed seeds stored for 1, 2, 3 and 4 weeks, respectively

3.2. Effect of post-hydropriming storage duration on the percentage of infected rice seeds

The percentage of infected seeds varied significantly with post-hydropriming storage duration ($p < 0.001$). Figure 2 illustrates the changes in seed infection percentage of CRAM 6 rice under the different treatments. The W0 treatment recorded the lowest infection percentage (0.20%), which was statistically similar to that of the Control treatment (1.11%). In contrast, seed infection percentage increased progressively with increasing storage duration after hydropriming. The highest infection percentage was observed in seeds stored for four weeks (W4), reaching 37.22%.

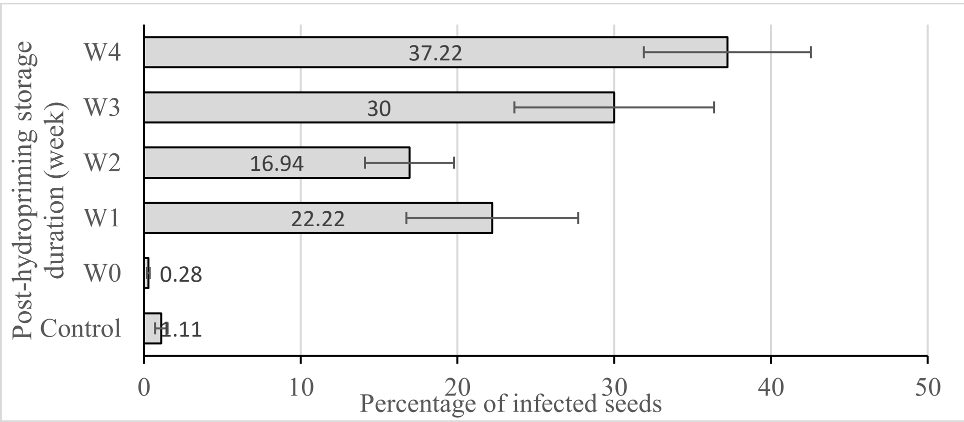

Figure 2. Effect of post-hydropriming storage duration on seed infection percentage in CRAM 6 rice. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3 and W4: hydroprimed seeds stored for 1, 2, 3 and 4 weeks, respectively.

3.3. Effects of hydropriming and seed storage duration on seedling emergence

The Kruskal-Wallis test revealed a highly significant effect of seed storage duration on all emergence parameters evaluated ($p < 0.001$). Regarding emergence onset time, hydroprimed seeds sown immediately after treatment (W0) exhibited the lowest value (4.42 days). The longest emergence onset times were observed in W1 (6.75 days) and W3 (6.42 days). Similarly, W0 recorded the shortest final emergence time (11.00 days), which was statistically similar to those obtained for the Control, W2, and W4 treatments (Table 2). In contrast, the longest final emergence time was observed in W1 (16.42 days), whereas W3 showed an intermediate value (14.17 days). Mean emergence time ranged from 6.36 to 10.56 days depending on the treatment. The lowest value was recorded for W0 (6.36 days). The Control and W4 treatments exhibited mean emergence times that were statistically similar to that of W0. Conversely, the highest values were observed in W1 (10.56 days) and W3 (9.75 days), while W2 (9.03 days) showed an intermediate response. For the emergence rate index, the highest values were recorded in W0 (3.63 seedlings day^{-1}) and the Control treatment (3.33 seedlings day^{-1}), which were statistically similar. In contrast, W1 exhibited the lowest emergence rate index (1.07 seedlings day^{-1}). Intermediate values, ranging from 1.43 to 1.95 seedlings day^{-1}, were observed in W2, W3, and W4 (Table 2). With respect to emergence percentage, W0 achieved the highest value (92.67%). The Control treatment recorded an emergence percentage of 83.67%, which was lower than that of W0 but higher than those observed in the remaining treatments. Emergence percentages of 40.67%, 59.67%, 50.67%, and 55.00% were recorded for W1, W2, W3, and W4, respectively, with no significant differences among these treatments (Figure 3).

Table 2: Effects of hydropriming and post-hydropriming storage duration on emergence parameters of CRAM 6 rice seedlings

Storage duration	Emergence onset time (day)	Final emergence time (day)	Mean emergence time (day)	Germination rate index (seed day^{-1})
Control	5,08 ± 0,37 ^{b}	12,50 ± 1,83 ^{ab}	7.48 ± 1.07 ^{ac}	3,33 ± 0,58 ^{a}
W0	4,42 ± 0,11 ^{a}	11,00 ± 1,95 ^{a}	6.36 ± 1.18 ^{a}	3,63 ± 0,90 ^{a}
W1	6,75 ± 1,82 ^{c}	16,42 ± 2,68 ^{c}	10.56 ± 1.39 ^{b}	1,07 ± 0,33 ^{d}
W2	6,00 ± 1,13 ^{bc}	13,50 ± 2,58 ^{ab}	9.03 ± 1.14 ^{bc}	1,79 ± 0,58 ^{bc}
W3	6,42 ± 1,08 ^{c}	14,17 ± 1,99 ^{b}	9.75 ± 1.37 ^{b}	1,43 ± 0,51 ^{cd}
W4	5,33 ± 0,65 ^{b}	12,67 ± 2,87 ^{ab}	7.76 ± 0.94 ^{ac}	1,95 ± 0,56 ^{b}
p	< 0,001	< 0,001	< 0,001	< 0,001

Values within a column followed by the same letter are not significantly different at the 5% level according to Dunn-Holm's multiple comparison test. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3, and W4: hydroprimed seeds stored for 1, 2, 3, and 4 weeks, respectively.

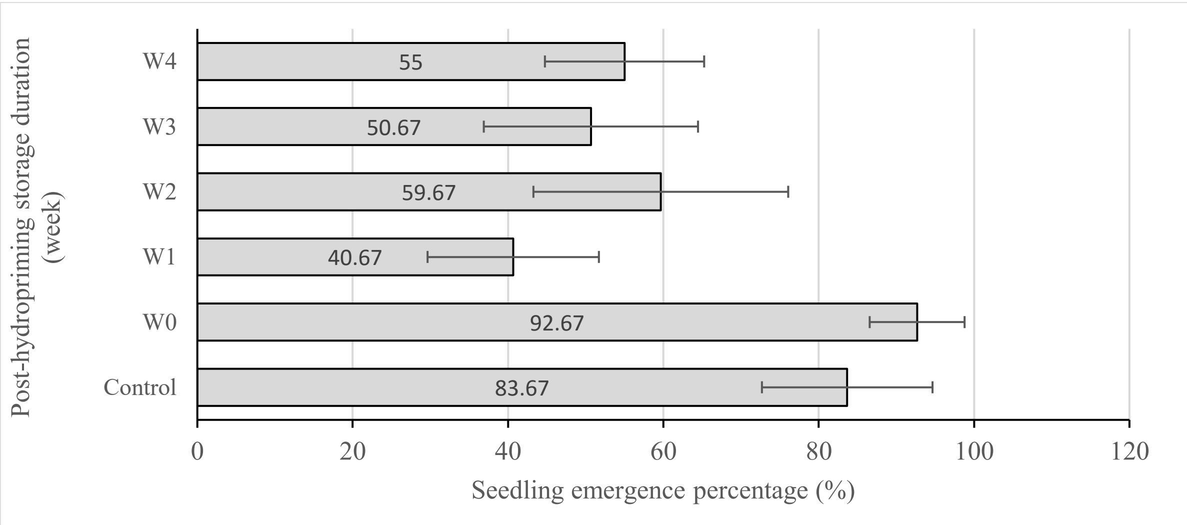

Figure 3: Effect of post-hydropriming storage duration on seedling emergence percentage of CRAM 6 rice seeds. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3 and W4: hydroprimed seeds stored for 1, 2, 3 and 4 weeks, respectively

3.4. Effects of hydropriming and seed storage duration on rice growth

The Kruskal-Wallis test revealed a significant effect of post-hydropriming storage duration on plant height, number of leaves, number of tillers, and root volume (Table 3). In contrast, root length was not significantly affected by seed storage duration. Hydroprimed seeds sown immediately after treatment (W0) produced the most vigorous plants, recording the highest values for plant height (75.50 cm), number of leaves (18.92), number of tillers (3.92), and root volume (14.38 cm^3). The Control treatment exhibited intermediate values of 69.29 cm, 16.92 leaves, 3.33 tillers, and 12.13 cm^3 for the same parameters.

Similarly, W1 and W2 displayed intermediate growth performance, whereas the lowest values were observed in W3 and W4. These two treatments were statistically similar for all growth parameters considered. Plant height, number of leaves, number of tillers, and root volume generally declined as storage duration increased after hydropriming. Unlike the other growth traits, root length showed limited variation among treatments, ranging from 30.83 to 34.58 cm. No significant differences were detected among storage durations for this parameter.

A significant effect of post-hydropriming storage duration was also observed for total dry biomass ($p < 0.05$). The highest total dry biomass was recorded in W0, with a mean value of 12.35 g (Figure 4). The Control and W1 treatments produced statistically similar biomass values of 10.25 g and 9.30 g, respectively. By contrast, the lowest biomass accumulation was observed in W2, W3, and W4, with values ranging from 5.38 to 5.75 g.

Table 3: Effects of hydropriming and post-hydropriming storage duration on growth parameters of CRAM 6 rice plants

Storage duration	Plant height (cm)	Number of leaves	Numbers of tillers	Root lenght (cm)	Root volume (cm^3)
Control	69,29±20,22 ^{b}	16,92±7,03 ^{b}	3,33±0,78 ^{b}	33,54±6,32 ^{a}	12,13±6,86 ^{b}
W0	75,50±15,25 ^{a}	18,92±4,94 ^{a}	3,92±0,67 ^{a}	34,58±12,63 ^{a}	14,38±7,76 ^{a}
W1	62,87±12,17 ^{c}	15,08±4,80 ^{c}	3,08±0,95 ^{bc}	32,75±6,70 ^{a}	10,67±2,39 ^{c}
W2	57,54±9,98 ^{d}	13,33±5,55 ^{d}	2,92±0,58 ^{c}	31,37±8,74 ^{a}	8,75±2,14 ^{d}
W3	53,33±9,59 ^{e}	12,00±3,86 ^{e}	2,75±0,85 ^{c}	31,6 ±7,40 ^{a}	7,17±2,72 e
W4	52,50 ±10,25 ^{e}	11,92±4,12 ^{e}	2,67±0,74 ^{c}	30,8 ±6,86 ^{a}	7,05±2,18 ^{e}
p	< 0,01	< 0,01	< 0,05	0.18 ^{ns}	< 0,05

Values within a column followed by the same letter are not significantly different at the 5% level according to Dunn-Holm's multiple comparison test. ns: not significant (p>0.05); Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3, and W4: hydroprimed seeds stored for 1, 2, 3, and 4 weeks, respectively.

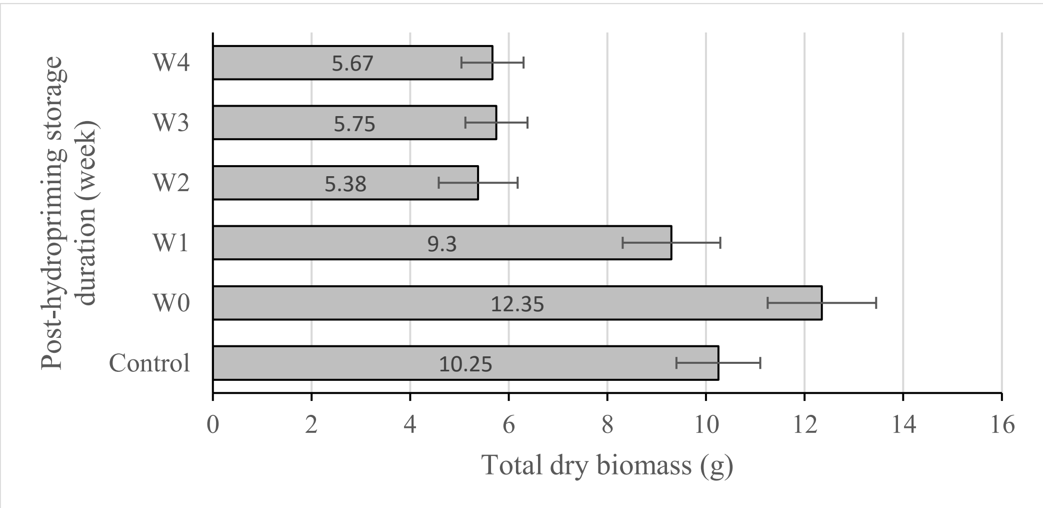

Figure 4: Effect of post-hydropriming storage duration on total dry biomass of CRAM 6 rice plants. Control: non-primed seeds; W0: hydroprimed seeds sown immediately after priming; W1, W2, W3 and W4: hydroprimed seeds stored for 1, 2, 3 and 4 weeks, respectively.

4. DISCUSSION

The results of the present study demonstrate that hydropriming markedly improved germination, seedling emergence, and early growth of CRAM 6 rice when seeds were sown immediately after treatment. Hydroprimed seeds without storage (W0) consistently exhibited superior performance in terms of germination and emergence timing, germination and emergence percentages, as well as growth traits and total dry biomass. These findings are consistent with those reported by Nakao *et al.,* (2020) and Sakagami *et al.,* (2024), who observed enhanced vigor in hydroprimed rice seeds. According to Varier *et al.,* (2010) and Paparella *et al.,* (2015), such improvements result from the early activation of physiological processes before sowing, including cellular repair mechanisms, protein synthesis, and enzyme activation. Sakagami *et al.,* (2024) further demonstrated that hydropriming stimulates α-amylase activity, thereby promoting faster mobilization of carbohydrate reserves required for embryo growth and seedling establishment. The improvement in germination observed in the present study was accompanied by enhanced emergence and more vigorous vegetative growth. Seeds sown immediately after hydropriming produced seedlings with a greater number of leaves and tillers, larger root systems, and higher total dry biomass. Similar observations were reported by Corbineau *et al.,* (2023), who showed that seed priming promotes faster and more uniform emergence through better synchronization of the physiological processes involved in germination and seedling establishment.

The beneficial effects of hydropriming, however, declined progressively as storage duration increased. This decline was reflected in reduced germination performance, lower emergence percentages, and poorer growth and biomass accumulation. Treatments W3 and W4 consistently produced the lowest values and were statistically similar for most of the variables evaluated, suggesting that the physiological advantages conferred by hydropriming had largely disappeared after several weeks of storage. This gradual loss of vigor agrees with the findings of Hussain *et al.,* (2015), who reported that the positive effects of priming are maintained only for a limited period and diminish as storage time increases. Likewise, Wang *et al.,* (2018) showed that prolonged storage of hydroprimed rice seeds may induce physiological deterioration characterized by reduced starch metabolism, depletion of endosperm reserves, accumulation of malondialdehyde, and decreased antioxidant enzyme activity. Such changes ultimately impair the ability of seeds to maintain vigor, resulting in poorer germination, emergence, and subsequent plant growth.

The progressive increase in seed infection observed during storage may also have contributed to the decline in performance. The development of microorganisms on stored seeds can damage embryonic tissues or consume reserves required for germination and early seedling growth (Chen and Arora, 2023; Kaur *et al*., 2022). This assumption is supported by the simultaneous reduction in germination percentage, emergence percentage, and growth parameters as storage duration increased. Unlike most growth traits, root length was not significantly affected by the treatments. This suggests that root elongation may be less sensitive to post-hydropriming storage than traits associated with shoot development or biomass production. In contrast, root volume decreased with increasing storage duration, indicating that storage influenced the overall development of the root system rather than its elongation.

The negative effects observed in the present study do not necessarily imply that post-hydropriming storage is always detrimental. The response largely depends on storage duration, storage conditions, and genotype. Bore *et al.,* (2023) reported that hydroprimed seeds of the rice variety NERICA 4 maintained high germination capacity for up to 90 days when stored at 25 °C and 65% relative humidity, with a decline in vigor becoming evident only after 120 days of storage. Similarly, Galappaththi *et al.,* (2020) found that storage at low temperature (8 °C) in hermetically sealed containers preserved the benefits of hydropriming for several months. These findings indicate that combining hydropriming with appropriate storage conditions can extend the persistence of the treatment effects. Consequently, the reduced performance recorded after several weeks of storage in the present study may be attributed to the ambient storage conditions used for CRAM 6 seeds.

Overall, the results demonstrate that hydropriming is an effective technique for improving crop establishment and early growth of CRAM 6 rice. To maximize its benefits, however, seeds should either be sown shortly after treatment or stored under carefully controlled temperature and humidity conditions that minimize physiological deterioration (Sano *et al*., 2022).

5. CONCLUSION

The present study demonstrated that hydropriming significantly enhances the germination, emergence, and early growth of CRAM 6 rice. Seeds sown immediately after hydropriming exhibited the best overall performance, characterized by faster germination, higher germination and emergence percentages, greater vegetative growth, and increased biomass accumulation compared with non-primed seeds. In contrast, the beneficial effects of hydropriming gradually declined as storage duration increased, resulting in reduced germination, emergence, and plant growth, together with a higher incidence of seed infection. These findings indicate that the effectiveness of hydropriming is closely influenced by post-priming storage duration and storage conditions. For the CRAM 6 variety, the use of seeds immediately after hydropriming is recommended to maximize crop establishment and early plant development. Further studies investigating alternative storage conditions and the physiological mechanisms underlying the loss of vigor in primed seeds would contribute to optimizing the practical application of this technique.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Approval

Not applicable. This study did not involve human participants or experimental animals requiring ethical approval.

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