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Effect of Different Priming Agents on Germination and Seedling Growth Parameters of Spring Rice Varieties in Bara, Nepal

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ABSTRACT

This experiment was carried out in Fish laboratory of National Agriculture Modernization Program, Program Implementation Unit, Bara, Nepal to determine the effects of different priming agents on the germination and seedling growth parameters of spring rice varieties. The research was conducted in a controlled laboratory setting based on a 2-Factor Completely Randomized Design. Factor A consisted of 3 spring rice varieties (Hardinath hybrid-1, Sukha dhan-3 and Chaite-5) and factor B consisted of 7 priming agents (Hydro, NaCl 5%, $ZnSO_4$ 2%, $FeCl_3$ 2%, PEG 6000 5%, Gibberellin 10 mg/L of water, and Cow urine 20 ml/L of water). The treatments were replicated three times. Parameters related to germination (germination percentage, germination index, mean germination time, germination energy) and seedling growth (root length, root weight, shoot length, shoot weight, root to shoot ratio, seedling vigor index) were recorded. The result showed significant variation for varieties, priming agents and their interactions on most of the germination and seedling growth parameters. Among the given varieties, Sukha dhan-3 performed overall better than others in terms of all the germination parameters and most of the seedling growth traits. Among the priming agents, gibberellin, PEG 6000 and hydropriming improved germination indices and seedling growth, while Cow urine also emerges as a promising option, particularly for Hardinath hybrid-1. The interaction effect exhibited that Sukhadhan-3 treated with gibberellin, PEG 6000 and hydro priming gave the best results, overall. Chaite-5 showed inferior performance as a variety and for the given priming agents as compared to other varieties. However, hydro and Cow Urine priming can be considered locally to enhance the germination and seedling growth parameters for the desired variety according to the preference of farmers and given climatic conditions.

Keywords Germination, Priming, Seedling growth parameters, Variety.

INTRODUCTION

Nepal is considered an agricultural country where around two-third of the population is directly in-

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volved in the agriculture sector, and this sector is responsible for up to 23.5% of the country's total GDP (Nepal Rastra Bank 2022). The agricultural landscape of Nepal is predominantly characterized by rice cultivation which occupies the largest share of arable land. The agriculture sector rose by 3.0% in Fiscal Year (FY) 2024 after rising by 2.8% in FY2023 mostly driven by increased rice production. The paddy yield, which holds for about 17% share of agriculture GDP, increased by 4.3% in FY2024, supported by normal monsoon, and timely availability of farm inputs, particularly chemical fertilizer (Asian Development Bank 2024).

In Nepal, rice cultivation is practiced mainly in Rainy season and spring season. While most of the attention is given to the Rainy Season Rice, spring rice also holds account for backing the food security and maintaining the balance (Regmi *et al.* 2023). Moreover, its production capacity is more in comparison to the Rainy Season Rice even though the production area is low (Niraula and Baral 2024).

Seed priming is a pre-sowing technique which involves soaking the seeds in water or any other desirable solution for a specific period of time which interferes with seed germination process and enhances it (Ebha and Karki 2023). Seed priming influences the seedling development by promoting metabolic activities before the emergence of radicle and improving germination rate and better plant performance on the actual field (Amir *et al.* 2024). Various studies on this field reveal that seed priming on any crop seed has a positive impact on germination rate, seedling establishment, crop stand, plant vigor, and overall plant performance throughout the growing period.

Spring rice is generally limited by poor germination and poor seedling establishment leading to a less vigor plant with weak crop establishment (Subedi *et al.* 2015). Germination and seedling establishment are two critical stages that determine the performance of the plant in the actual field (Dhami *et al*. 2024). Moreover, weak seedlings are susceptible various kinds of abiotic and biotic stresses. Due to gap in the canopy from poor germination and less vigors plant, weed emerges and establish itself quickly and competes for space, light and nutrients resulting in reduction of yield for the main plant (Subedi *et al.* 2015). Even crop failure might occur due to poor germination and poor seedling establishment (Dhami *et al.* 2024). Seed priming technique had demonstrated to increase the overall germination rate, with improved agronomic traits of plants in the field (Ebha and Karki 2023). After priming rice seed develops a strong seedling quality, rapid emergence and high seedling rate, all of which contributes to increased yield at harvest. Hence, this study was carried out to determine the potential priming agents that enhances early vigor and growth of popular spring rice varieties of Nepal.

MATERIALS AND METHODS

Research site and time period

The experiment was conducted in the Fish laboratory of National Agriculture Modernization Program, Program Implementation Unit, Bara, located at an altitude of 103 meters above sea level (27º 02' 0'' N, 85º 0' 0'' E). Spanning from 19th May to 3rd July 2025, the study assessed key physiological responses under controlled conditions, ensuring precise observation of germination and early seedling growth.

Climatic conditions during the research period

The climatic data from 19th May to 3rd June, 2025 were taken to consideration for this analysis (Fig.1).

Experiment details

The details of the experiment are discussed below (Table 1).

Preparation of priming solutions

All the priming agent solutions were prepared in a 100 mL solution. The calculation of priming treatments was done by using the following formula (Harvey 2000):

Weight-to-volume % (%w/v) = gm solute/100 mL solution

Post priming operations

After 24 hrs of priming, the soaked seeds were removed and placed in a paper towel for 12 hrs until the

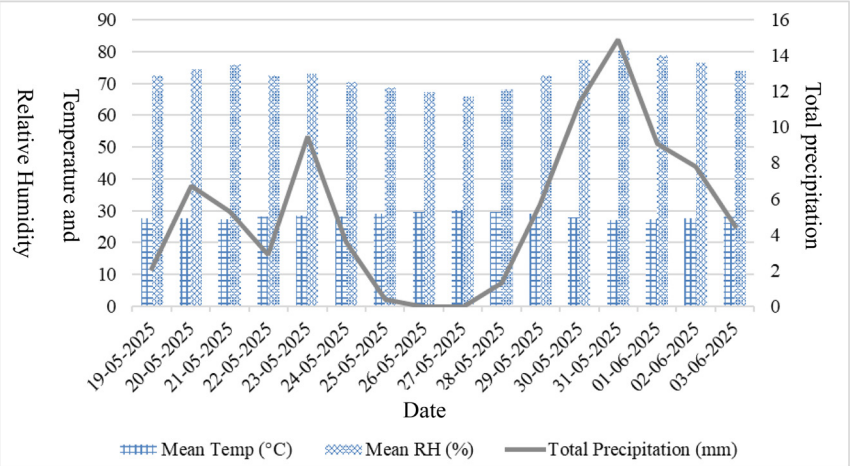

Fig. 1. Climatic data of Kalaiya, Bara from May 19th to June 3rd, 2025.

moisture absorbed by the seeds reduced to its original weight. Out of 20 grams of seeds that were primed, 30 seeds were selected for each treatment.

Medium of germination

Filter paper was used as a substrate in the petri plate for germination. The seeds were uniformly distributed on the sterile petri plate to test for germination under controlled condition. The filter paper was changed every 2 days to avoid any kind of contamination. The petri dishes were remained covered for 5 days, after which they were uncovered once more than 50% of the seeds had germinated.

Table 1. Details of experiment.

Design	Two factorial complete randomized design
Factor A	Three spring rice varieties 1. Hardinath hybrid-1 2. Sukha dhan-3 3. Chaite-5
Factor B	Seven priming agents 1. Hydro 2. Sodium chloride (NaCl) 5% 3. Gibberellin 10 mg/liter of water 4. Polyethylene glycol (PEG) 6000 5% 5. Zinc sulfate ($ZnSO_4$) 2% 6. Ferric chloride ($FeCl_3$) 2% 7. Cow urine 20 mL/ liter of water
Replication	3
Total experimental plots	63

Data collection parameters

The number of germinated seeds was recorded daily from the first day until the 7th day, when germination stabilizes, with minimal variation observed on consecutive days. On the 12th day, root length, shoot length, fresh shoot weight, and fresh root weight were measured. Subsequently, the roots and shoots from each treatment were oven dried at 85ºC for 48 hrs, after which their dry weights were recorded (Veerendra *et al.* 2023).

Seed germination percentage (%)

The germination percentage was calculated using the following formula (Kader 2005):

$$\text{Seed germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds}} \times 100\%$$

Mean Germination Time (MGT)

The given formula was used to calculate mean germination time (Kader 2005).

$$MGT = \frac{\sum(D * n)}{\sum n}$$

Where D represents the number of days counted from the onset of germination, and n denotes the number of seeds that germinated each day.

Germination Energy (GE)

Germination energy was calculated as (Yadav *et al.* 2023)

Germination Energy (GE) = % of seed germinated in 72 hrs

Germination Index (GI)

This parameter was calculated as (Kader 2005)

$$GI = \sum\left(\frac{Gi}{D}\right)$$

Gi = Number of seeds germinated on i^{th} day (sum across replications)

$$D = i^{th} \text{ day}$$

Root and Shoot Length

After 12 days, 10 sample plants were carefully removed from the petri dishes, and the root length was measured from the tip of the root apex to the root base and shoot length was measured from the tip of the shoot apex to the shoot base.

Root and Shoot Fresh weight

Twenty sample plants from each experimental unit were collected, and the roots and shoots were carefully separated using a knife. The root and shoot portions were then weighed on a precision scale separately, and the weight was recorded in grams and averaged for each treatment.

Root and Shoot Dry Weight

After recording the fresh weight of the root and shoot portion, the roots and shoots were wrapped in aluminum foil separately and left to dry for 48 hrs at 85ºC in the hot air oven (Veerendra *et al.* 2023). After the drying period, the dry weight of the roots and shoots were measured.

Root to Shoot Ratio (RSR)

Root to shoot ratio was calculated using following formula:

$$RSR = \frac{\text{Root length (cm)}}{\text{Shoot length (cm)}}$$

Seedling Vigor Index (SVI)

Seedling Vigor Index was calculated through the following formula (Yadav *et al*. 2023):

$$SVI = \frac{\text{Mean seedling length} \times \text{Germination percentage}}{100}$$

Statistical analysis

The recorded data were organized and tabulated in a Microsoft Excel version 2021. All calculations were performed in Excel and subsequently processed for analysis in R Studio version 4.4.2, and conclusions were drawn based on the results.

RESULTS AND DISCUSSION

Effect of variety on germination and seedling growth parameters

Effect on germination parameters due to variety

The analysis of variance revealed significant differences among the tested varieties for all of germination parameters (Table 2). Germination percentage varied significantly, with Sukha dhan-3 recording the highest value of 94.76%, which was statistically higher than Hardinath hybrid-1 with 86.98% and Chaite-5 with 86.03%. Germination energy and germination

Table 2. Effect of varieties and priming agents on germination parameters at Kalaiya, Bara, during 2025.

Variety	Germination percentage	Germination energy (%)	Mean germination time (days)	Germination index
Hardinath hybrid-1	86.98^{b}	85.24^{b}	2.08^{b}	43.19^{b}
Sukha dhan-3	94.76^{a}	92.70^{a}	1.69^{c}	56.79^{a}
Chaite-5	86.03^{b}	83.17^{b}	2.19^{a}	41.03^{b}
LSD (5%)	3.11	3.27	0.1	2.2
F-Probability	***	***	***	***
SEm	2.765	2.89	0.15	4.93
Priming agent				
Hydro	93.33^{a}	91.11^{a}	1.79^{c}	53.06^{b}
NaCl	84.07^{b}	77.04^{c}	2.86^{a}	30.11^{e}
Gibberellin	92.59^{a}	90.37^{a}	1.52^{d}	59.34^{a}
PEG 6000	88.52^{ab}	87.41^{ab}	1.82^{c}	49.54^{c}
$ZnSO_4$	88.89^{ab}	88.15^{ab}	2.12^{b}	42.26^{d}

Table 2. Continued.

Variety	Germination percentage	Germination energy (%)	Mean germination time (days)	Germination index
$FeCl_3$	85.56[b]	84.07[b]	2.06[b]	41.35[d]
Cow urine	91.85[a]	91.11[a]	1.73[c]	53.40[b]
LSD (5%)	4.74	4.99	0.15	3.36
F-Probability	**	***	***	***
SEm	1.34	1.92	0.16	3.7
CV (%)	5.59	6.03	7.86	7.52
Grand mean	89.26	87.04	1.98	47

Note: Treatments means with distinct alphabetical letters signify significant differences determined by the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. **Significant at 1% level of significance, ***Significant at 0.1% level of significance, LSD: Least significant difference, SEm: Standard error of the mean, CV: Coefficient of variation.

index were significantly higher in Sukha dhan-3 with 92.70% and 56.79 respectively indicating its superiority in seed vigor than other two varieties. The lowest germination energy and germination index were recorded for Chaite-5 with 83.1% and 41.30 respectively which were statistically similar to the germination energy and germination index of Hardinath hybrid-1 with 85.24% and 43.19 respectively. Sukhadhan-3 also observed the lowest mean germination time with 1.69 days indicating a faster and uniform germination process varying significantly with Hardinath hybrid-1 and Chaite-5, having mean germination time of 2.08 days and 2.19 days, respectively.

Effect on seedling growth parameters due to variety

Seedling growth parameters including root length, shoot length, root shoot ratio, root fresh weight, root dry weight and seedling vigor index showed significant differences while shoot fresh weight and shoot dry weight showed no significant differences within the given varieties (Table 3). Highest root length (5.61cm) was found in Sukha dhan-3 whereas highest shoot length was found in Hardinath hybrid-1 (7.57 cm). Root to shoot ratio was significantly higher for Sukha dhan-3 (0.85). Root fresh and dry weight were significantly higher for Sukha dhan-3 while root fresh weight was statistically similar to that of Hardinath

Table 3. Effect of varieties and priming agents on seedling growth parameters at Kalaiya, Bara, during 2025.

Variety	Root length (cm)	Shoot length (cm)	Root : Shoot	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)	Seedling vigor index
Hardinath hybrid-1	4.54[b]	7.57[a]	0.59[b]	0.33[a]	0.31	0.06[a]	0.08	10.54[b]
Sukha dhan-3	5.61[a]	6.53[b]	0.85[a]	0.34[a]	0.32	0.07[a]	0.08	11.55[a]
Chaite-5	4.03[c]	6.05[c]	0.66[b]	0.25[b]	0.29	0.06[b]	0.08	8.65[c]
LSD	0.51	0.30	0.07	0.08	–	0.01	–	0.75
F-Probability	***	***	***	*	NS	***	NS	***
SEm	0.47	0.45	0.08	0.03	0.01	0.003	0.001	0.85
Priming agent								
Hydro	5.29[a]	7.08[ab]	0.75[a]	0.31	0.28	0.067	0.09	11.62[a]
NaCl	5.34[a]	6.76[b]	0.79[a]	0.41	0.34	0.064	0.08	10.24[bc]
Gibberellin	5.22[a]	6.75[b]	0.78[a]	0.32	0.32	0.066	0.07	11.08[ab]
PEG 6000	5.44[a]	6.75[b]	0.81[a]	0.30	0.32	0.064	0.08	10.82[ab]
$ZnSO_4$	2.31[c]	5.23[c]	0.46[b]	0.23	0.30	0.057	0.07	6.68[d]
$FeCl_3$	3.74[b]	7.51[a]	0.50[b]	0.26	0.28	0.065	0.08	9.60[c]
Cow urine	5.74[a]	6.92[b]	0.84[a]	0.36	0.33	0.070	0.08	11.68[a]
LSD (5%)	0.78	0.46	0.11	–	–	–	–	1.15
F-Probability	***	***	***	NS	NS	NS	NS	***
SEm	0.47	0.27	0.06	0.02	0.01	0.002	0.002	0.66
CV (%)	17.27	7.22	16.21	42.88	22.17	14.43	19.49	11.75
Grand mean	4.73	6.72	0.70	0.31	0.31	0.06	0.08	10.25

Note: Treatments means with distinct alphabetical letters signifies significant differences determined by the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. *Significant at 5 % level of significance, ***Significant at 0.1 % level of significance, NS: Non-significant, LSD: Least significant difference, SEm: Standard error of the mean, CV: Coefficient of variation.

Table 4. Effect of interaction between varieties and priming agents on germination parameters at Kalaiya, Bara during 2025.

Variety	Priming agent	Germination percentage	Germination energy (%)	Mean germination time (days)	Germination index
Hardinath hybrid-1	Hydro	94.44^{abc}	91.11^{abc}	2.04^{cdef}	48.16^{cd}
	NaCl	86.67^{bcde}	85.56^{bcde}	2.61^{b}	33.47^{i}
	Gibberellin	87.78^{bcde}	84.44^{cde}	1.75^{fg}	50.95^{bc}
	PEG 6000	81.11^{def}	80.00^{de}	2.06^{cde}	40.53^{efgh}
	$ZnSO_4$	85.56^{cdef}	84.44^{cde}	2.22^{cd}	38.61^{ghi}
	$FeCl_3$	78.89^{ef}	77.78^{e}	1.90^{efg}	41.34^{efgh}
	Cow urine	94.44^{abc}	93.33^{abc}	1.95^{defg}	49.27^{c}
Sukha dhan-3	Hydro	97.78^{a}	96.67^{a}	1.40^{h}	64.95^{a}
	NaCl	88.89^{abcd}	78.89^{de}	2.84^{b}	32.46^{i}
	Gibberellin	95.56^{ab}	95.56^{ab}	1.13^{h}	70.83^{a}
	PEG 6000	97.78^{a}	96.67^{a}	1.38^{h}	65.61^{a}
	$ZnSO_4$	92.22^{abc}	91.11^{abc}	1.89^{efg}	47.96^{cd}
	$FeCl_3$	95.56^{ab}	94.44^{abc}	1.97^{defg}	47.05^{cde}
	Cow urine	95.56^{ab}	95.56^{ab}	1.21^{h}	68.66^{a}
Chaite-5	Hydro	87.78^{bcde}	85.56^{bcde}	1.93^{defg}	46.06^{cdef}
	NaCl	76.67^{f}	66.67^{f}	3.13^{a}	24.40^{j}
	Gibberellin	94.44^{abc}	91.11^{abc}	1.69^{e}	56.26^{b}
	PEG 6000	86.67^{bcde}	85.56^{bcde}	2.03^{def}	42.47^{defg}
	$ZnSO_4$	88.89^{abcd}	88.89^{abcd}	2.21^{cd}	40.14^{fgh}
	$FeCl_3$	82.22^{def}	80.00^{de}	2.32^{c}	35.65^{hi}
	Cow urine	85.56^{cdef}	84.44^{cde}	2.01^{def}	42.27^{defg}
LSD (5%)		8.22	8.64	0.26	5.83
F-Probability		*	***	***	***
SEM		1.36	1.67	0.12	2.71
CV (%)		5.59	6.03	7.86	7.52
Grand Mean		89.25	87.04	1.98	47

Note: Treatments means with distinct alphabetical letters signify significant differences determined by the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. *Significant at 5% level of significance, ***Significant at 0.1% level of significance, LSD: Least significant difference, SEm: Standard error of the mean, CV: Coefficient of variation.

hybrid-1. The seedling vigor index varied significantly where Sukha dhan-3 produces the highest value (11.55) superior to Hardinath hybrid-1 (10.54) and Chaite-5 (8.65).

Effect of priming agents on germination and seedling growth parameters

Effect on germination parameters due to priming agents

Different priming agents showed significant variation for the germination parameters (Table 2). Hydro priming showed the highest germination percentage (93.33%) which is statistically similar with the germination percentage obtained with gibberellin (92.59%) and cow urine (91.85%). Germination energy varied significantly, where hydro and cow urine priming obtained the highest value of 91.11% which is statistically similar to the value observed for gibberellin (90.37%). Gibberellin showed the lowest mean germination time (1.52 days), while those primed with NaCl showed the highest mean germination time (2.86 days). Germination index also showed a significant variation among different priming agents, where gibberellin (59.34) outperformed other priming agents followed by cow urine (53.40) and hydro priming (53.06) which were statistically similar to each other.

Effect on seedling growth parameters due to priming agents

Seedling growth parameters varied markedly among different priming agents (Table 3). Cow urine produces maximum root length (5.74 cm) which was statistically similar to that of PEG 6000 (5.44 cm), NaCl (5.34 cm), hydro (5.29 cm) and gibberellin

(5.22 cm). $FeCl_3$ showed highest shoot length (7.51 cm) which was statistically similar to that obtained from hydro (7.08 cm) which is also statistically similar with shoot length observed from cow urine treatment (6.92 cm). Highest root to shoot ratio was obtained with cow urine priming (0.84) which is statistically similar with the ratio observed with PEG 6000 (0.81). Biomass indicating parameters which include root and shoot dry and fresh weights were found to be non-significant with the given priming agents. Seedling vigor index showed considerable variation within the given priming agents with cow urine (11.68) having highest value which was statistically similar to that of hydro priming (11.62), while $ZnSO_4$ (6.68) showed the lowest value.

Effect of interaction between varieties and priming agents on germination and seedling growth parameters

Effect on germination parameters due to interaction

The interaction effects of rice varieties with different priming agents showed significant differences in germination parameters (Table 4).

Germination percentage was highest for Sukha dhan-3 (97.78%) when hydro and PEG 6000 priming. However, Sukha dhan-3 performed consistently for most of the treatments like gibberellin, $FeCl_3$ and cow urine, giving similar results (95.56%) while priming with NaCl showed the lowest germination percentage (88.89%), which was not significantly different. Hardinath hybrid-1 performed better with hydro and cow urine (94.44%) priming, whereas Chaite-5 only performed well when primed with gibberellin (94.44%).

Germination energy was highly significant, where Sukha dhan-3 gave the highest value (96.67%) when primed with hydro and PEG 6000. Gibberellin (95.56%), cow urine (95.56%), $FeCl_3$ (94.44%), and $ZnSO_4$ (91.11%) also showed statistically similar results, while NaCl (78.89%) showed the lowest germination energy for Sukha dhan-3. Hardinath hybrid-1 observed the highest germination energy (93.33%) when primed with cow urine, and hydro priming (91.11%) also showed statistically similar results. The lowest value for germination energy in Hardinath hybrid-1 was observed with $FeCl_3$ (77.78%). Chaite-5 observed the highest germination energy for gibberellin (91.11%) and lowest with NaCl (66.67%).

Mean germination time was highly significant for the interaction effect of rice varieties and priming agents. Sukha dhan-3 observed lowest mean germination time (1.40 days) with hydro priming which was statistically similar to PEG 6000 (1.38 days), cow urine (1.21 days) and gibberellin (1.13 days) whereas highest mean germination time for Sukha dhan-3 was observed with NaCl (2.84 days). Hardinath hybrid-1 obtained lowest mean germination time for gibberellin (1.75 days) and highest with NaCl (2.61 days). Similarly, Chaite-5 showed lowest mean germination time with gibberellin (1.69 days) and highest with NaCl (3.13 days).

Germination index was found to be highly significant for the interaction effect. Highest germination index was observed for Sukha dhan-3 when primed with gibberellin (70.83) which was statistically similar with cow urine (68.66), PEG 6000 (65.61) and hydro (64.95) priming while lowest value for Sukha dhan-3 was observed when primed with NaCl (32.46). Whereas for Hardinath hybrid-1 highest value of germination index was obtained with gibberellin (50.95) and the lowest with NaCl (33.47). Likewise, for Chaite-5, the highest germination index was obtained with gibberellin (56.26) and lowest with NaCl (24.40).

Effect on seedling growth parameters due to interaction

Seedling germination parameters did not show a significant difference for the interaction effect of spring rice varieties and priming agents, except for root dry weight (Table 5). Although a non-significant result, numerically the highest root length was observed for Sukha dhan-3 when primed with PEG 6000 (7.13 cm), and the lowest root length was observed for Hardinath hybrid-1 when primed with $ZnSO_4$ (1.76 cm). Similarly, the highest shoot length was seen in Hardinath hybrid-1 when primed with $FeCl_3$ (8.47 cm) and the lowest was observed for Chaite-5 when

Table 5. Effect of interaction between varieties and priming agents on seedling growth parameters at Kalaiya, Bara, during 2025.

Variety	Priming agent	Root length (cm)	Shoot length (cm)	Root: Shoot	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (g)	Shoot dry weight (g)	Seedling vigor index
Hardinath-hybrid-1	Hydro	5.3	7.89	0.67	0.35	0.32	0.08^{a}	0.08	12.46
	NaCl	5.6	7.29	0.77	0.4	0.34	0.07^{abcde}	0.07	11.14
	Gibberellin	5.29	7.77	0.68	0.37	0.29	0.06^{bcde}	0.07	11.45
	PEG 6000	5.37	7.85	0.7	0.36	0.34	0.06^{de}	0.08	10.7
	$ZnSO_4$	1.76	5.99	0.29	0.2	0.3	0.05^{e}	0.08	6.61
	$FeCl_3$	3.44	8.47	0.4	0.24	0.26	0.06^{de}	0.08	9.36
	Cow urine	4.98	7.73	0.64	0.41	0.33	0.06^{bcde}	0.09	12.03
Sukha dhan-3	Hydro priming	6.47	6.71	0.97	0.32	0.3	0.06^{cde}	0.09	12.89
	NaCl	6.07	6.52	0.93	0.56	0.34	0.07^{abcde}	0.07	11.29
	Gibberellin	5.71	6.57	0.86	0.33	0.37	0.07^{abcd}	0.06	11.77
	PEG 6000	7.13	6.68	1.07	0.33	0.35	0.08^{ab}	0.09	13.51
	$ZnSO_4$	2.94	4.98	0.6	0.31	0.31	0.06^{bcde}	0.06	7.3
	$FeCl_3$	4.27	7.25	0.59	0.25	0.26	0.08^{ab}	0.09	10.97
	Cow urine	6.71	6.99	0.96	0.36	0.34	0.08^{abc}	0.07	13.08
Chaite-5	Hydro priming	4.1	6.64	0.61	0.26	0.24	0.06^{de}	0.09	9.49
	NaCl	4.33	6.48	0.67	0.28	0.34	0.06^{cde}	0.08	8.29
	Gibberellin	4.67	5.92	0.79	0.26	0.29	0.06^{cde}	0.07	10.01
	PEG 6000	3.8	5.73	0.66	0.2	0.27	0.06^{de}	0.08	8.24
	$ZnSO_4$	2.22	4.71	0.48	0.18	0.3	0.06^{de}	0.08	6.14
	$FeCl_3$	3.52	6.81	0.52	0.29	0.31	0.06^{cde}	0.08	8.48
	Cow urine	5.53	6.05	0.91	0.3	0.31	0.07^{abcd}	0.07	9.93
LSD (5%)		–	–	–	–	–	0.01	–	–
F-Probability		NS	NS	NS	NS	NS	*	NS	NS
SEM		0.31	0.21	0.04	0.02	0.01	0.002	0.002	0.47
CV (%)		17.27	7.22	16.21	42.88	22.17	14.43	19.49	11.75
Grand mean		4.73	6.72	0.70	0.31	0.31	0.06	0.08	10.25

Note: NaCl: Sodium Chloride, PEG: Polyethylene glycol, $ZnSO_4$: Zinc sulphate, $FeCl_3$: Ferric chloride. Treatments means with distinct alphabetical letters signifies significant differences determined by the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. *Significant at 5% level of significance, LSD: Least significant difference, SEm: Standard error of the mean, CV: Coefficient of variation.

primed with $ZnSO_4$ (4.71 cm).

For root to shoot ratio, the highest value was observed in Sukha dhan-3 with PEG 6000 (1.07) and the lowest was observed for Hardinath hybrid-1 (0.29).

In case of root fresh weight, the highest value was obtained for Sukha dhan-3 in priming with NaCl (0.56 g) and lowest value was obtained for Chaite-5 in priming with $ZnSO_4$ (0.18 g).

For shoot fresh weight, Sukha dhan-3 showed the highest value with gibberellin (0.37 g) and lowest value was observed in Chaite-5 with hydro (0.24 g) priming.

Root dry weight showed a significant difference for the interaction effect where Hardinath hybrid-1 showed highest root dry weight when hydro priming (0.08 g) which is statistically similar with the dry weight obtained for Sukha dhan-3 when primed with PEG 6000 (0.08 g), $FeCl_3$ (0.08 g) and cow urine (0.08 g). The lowest root dry weight was obtained for Hardinath hybrid-1 when primed with $ZnSO_4$ (0.05 g).

For shoot dry weight the value for the interaction effect ranges from 0.09 g to 0.06 g, showing no significant differences.

Lastly, the seedling vigor index is non-significant with the interaction effect, although the highest value

for seedling vigor index was observed for Sukha dhan-3 when primed with PEG 6000 (13.51), and the lowest value was obtained for Chaite-5 when primed with $ZnSO_4$ (6.14).

DISCUSSION

Discussion on effects of varieties on germination and seedling growth parameters

Among the three rice varieties (Hardinath hybrid-1, Sukha dhan-3, and Chaite-5), Sukha dhan-3 performed consistently better than the other two in terms of germination and seedling growth parameters, which occurred because the inherent drought tolerance of this variety was complemented by the optimum conditions provided. Previous studies have also reported that Sukha dhan varieties were more responsive to different priming agents compared to the moderate response of Hardinath hybrid-1 (Devkota *et al.* 2023; Poudel *et al.* 2023; Subedi *et al.* 2015). Chaite-5 relatively showed lower performance in all aspects which may be due to the genetic makeup of the variety (Regmi *et al.* 2023).

Discussion on effects of priming agents on germination and seedling growth parameters

Priming agents significantly improved the germination and seedling growth parameters. Gibberellin priming showed the highest germination index, lowest mean germination time and better germination percentage and energy which aligns with previous research findings (Dhami *et al.* 2024). Moreover previous study also suggested hormonal priming accelerates metabolic activities and promotes uniform germination (Amir *et al.* 2024). PEG 6000 primed seed displayed good seed and seedling vigor due to controlled hydration, reduced reactive oxygen species accumulation and protecting cells from oxidative damage (Amir *et al.* 2024). Hydro priming also displayed better results for most of the germination and seedling parameters, supported by findings from Dhami *et al.* (2024) suggesting simple water soaking is effective in activating enzymatic processes. Cow urine on the other hand also significantly improved germination and seedling growth parameters which may be due to presence of nutrients like nitrogen and potassium (Ebha and Karki 2023). Nutrient priming with $ZnSO_4$ and $FeCl_3$ showed mixed responses where zinc priming majorly contributed for the biomass related trait, consistent with previous findings (Devkota *et al.* 2023). Moreover, priming with NaCl delayed the germination in comparison with other priming agents, but the root to shoot ratio was relatively high, reflecting increased tolerance for stress conditions and for effective nutrient uptake.

Discussion on effects of interaction between variety and priming agents on germination and seedling growth parameters

The interaction effects showed that different varieties respond differently to priming agents. Sukhadhan-3 performed relatively better with PEG 6000, gibberellin, and hydro priming in contrast with other priming agents (Poudel *et al.* 2023; Subedi *et al.* 2015). Hardinath hybrid-1 responded well with cow urine, gibberellin and hydro priming by showing improvement in seedling vigor (Devkota *et al.* 2023). As Hardinath hybrid-1 variety is getting popular for spring season cultivation, the application of readily available local resources as priming agent could be beneficial for proper seed germination and better seedling establishment. Chaite-5 showed poor response to most of the priming agents yet cow urine, gibberellin and hydro priming can be considered to relatively increase the germination and better seedling establishment instead of using unprimed seeds directly.

CONCLUSION

The study showed significant differences among varieties, priming agents and their interaction for germination and seedling growth parameters. Germination and seedling growth parameters were enhanced for hydro, gibberellin, PEG 6000 and cow urine primed seeds. Cow urine gave statistically similar results as of gibberellin and hydro priming particularly in Hardinath hybrid-1 which suggests a low-cost method for the enhancement of germination and seedling growth parameters. Sukha dhan-3 consistently performed better for the germination and seedling growth parameters among the varieties. The interaction effects revealed all of the varieties performed better under gibberellin, PEG 6000, cow urine and

hydro priming which suggests any of these priming agents can be used to enhance germination and seedling performance for the desired variety. Hence, the findings indicate that priming is an effective and low-cost environmentally friendly technique for early germination and growth of seedlings in spring season rice to ensure better crop establishment and overall performance on the field.

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