



## Effect of Different Priming Agents on Germination and Early Seedling Growth of Maize (*Zea mays L.*) in Khairahani, Chitwan

Mohammad Yunush Idrishi, Achyut Gaire\*

Institute of Agriculture and Animal Science, Rampur Campus, Khairahani, Chitwan, Nepal

\*Corresponding author's email: [achyut.gaire@rc.tu.edu.np](mailto:achyut.gaire@rc.tu.edu.np)

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### ABSTRACT

Maize (*Zea mays L.*) is a second most important staple crop in Nepal, yet its productivity remains below potential due to poor seed quality and low germination. Seed priming is a simple and cost-effective approach to improve germination, seedling vigor, and crop establishment. A laboratory experiment was conducted in January 2025 at Rampur Campus, Chitwan, using a Completely Randomized Design (CRD) with three replications and nine treatments: hydro-priming (24 hrs), NaCl (1%), urea (0.5% and 1%), KNO<sub>3</sub> (1% and 2%), GA<sub>3</sub> (50 ppm and 75 ppm), and control, to evaluate their effects on maize germination and early seedling growth under controlled conditions. Seeds were soaked for 24 hrs, dried for 12 hrs, and germinated in Petri plates at 25 ± 2°C. Observations were recorded at 12-hour intervals on different germination parameters of seed. Results showed that GA<sub>3</sub> 75 ppm and urea 1% were the most effective treatments, achieving the highest germination percentage (75.19% and 74.63%), seedling vigor index (5717.14 and 4583.23), germination energy (76 both), germination index (13.76 and 13.78), radicle length (59.39 and 47.53 mm), plumule length (7.66 and 6.65 mm), and radicle to plumule ratio (7.78 and 7.34), followed by Hydro-priming and NaCl 1%. In contrast, control seeds showed the lowest values across all traits. Early germination (12-36 hours) showed significant improvement, whereas later stages were non-significant. Overall, seed priming markedly enhanced germination, seedling vigor, and early growth. Among the tested treatments, GA<sub>3</sub> at 75 ppm and urea at 1% emerged as the most effective priming agents for enhancing germination and early seedling growth of maize.

**Keywords:** Germination, Hydro-priming, Maize, Seed Priming, Seedling Vigor.

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### INTRODUCTION

Maize (*Zea mays L.*) is the second most important cereal crop in Nepal after rice, serving as a major source of food, feed, and industrial raw material. In 2024, maize was cultivated on 916,004 ha with a total production of 3,193,869 tons and an average productivity of 3.49 t ha<sup>-1</sup> (MoALD 2024). Maize productivity in the country largely depends on the use of quality seed, which ensures genetic purity, high germination, seed vigor, and uniform crop establishment. Despite its importance, the seed replacement rate in maize remains low, as a large proportion of farmers continue to rely on farm-saved seed, thereby constraining yield potential (Gairhe et al 2021, NSSTRC 2022). Besides seed quality, optimum plant population also strongly influences yield. Low plant density wastes resources, while high density increases competition, reducing ear size and grain weight (Mourtzinis et al 2018). Thus, quality seed and optimum density are critical for maize productivity and food security in Nepal.

Seed priming, a pre-sowing treatment regulating hydration and metabolism before radicle protrusion, improves emergence, vigor, and yield under stress (Johnson and Puthur 2021). Since its development in the 1970s with polyethylene glycol and salts, techniques have expanded to hydro-priming, osmo-priming, halo-priming, hormonal priming, and bio-priming, offering practical, low-cost options for crop improvement.

Seed germination is a tightly regulated process controlled by hormonal interactions, particularly the balance between Gibberellic acid (GA) and abscisic acid (ABA), with environmental factors like light and temperature influencing seedling establishment (Xie et al 2022). Several studies have documented the positive effects of seed priming on germination, vigor, stress tolerance, and crop establishment (Ali et al 2022). Treatments such as

GA<sub>3</sub>, salicylic acid, nutrient priming, hydro-priming, and bio-priming enhance enzymatic activity, osmolyte accumulation, antioxidant defense, and stress resilience (Ma et al 2024). Nutrient priming with FeSO<sub>4</sub> has also been shown to accelerate germination and enhance seedling mass under nutrient-limited conditions, while hydro-priming and smoke water treatments improve germination and early growth by lowering ABA levels and stimulating enzyme activity (Lamichhane et al 2024).

Research has shown that seed priming with agents such as KNO<sub>3</sub>, GA<sub>3</sub>, PEG, and bio-priming can significantly enhance maize germination, vigor, and stress tolerance under rainfed and adverse conditions. Techniques like hydro, osmo and halo-priming have also improved emergence and resilience to cold, drought, and salinity stresses (Pokhrel 2024). However, adoption remains very limited, as most farmers still practice only simple hydro-priming, which is less effective than hormonal or nutrient-based methods. Consequently, poor germination, weak crop stands, and low yields continue to constrain maize productivity. Effective seed priming, therefore offers a practical pathway to strengthen crop establishment, reduce yield gaps, and support sustainable maize production in Nepal.

## MATERIALS AND METHODS

The experiment was conducted in the laboratory of Rampur Campus, Institute of Agriculture and Animal Science (IAAS), Chitwan, Nepal (27°37.019'N, 84°33.9661'E) at an altitude of 198 meters in January 2025. It was laid out in a Completely Randomized Design (CRD) with three replications and nine treatments, including hydro-priming (24 hours), NaCl 1%, Urea 0.5%, Urea 1%, KNO<sub>3</sub> 1%, KNO<sub>3</sub> 2%, GA<sub>3</sub> 50 ppm, GA<sub>3</sub> 75 ppm, and an unprimed control. Priming solutions were prepared using 250 ml of distilled water, with corresponding solute concentrations: 2.5 g NaCl for 1% salt, 1.25 g and 2.5 g urea for 0.5% and 1%, 2.5 g and 5 g KNO<sub>3</sub> for 1% and 2%, and 12.5 mg and 18.75 mg GA<sub>3</sub> for 50 ppm and 75 ppm, respectively. Maize seeds of variety Rampur Hybrid-10 were soaked in each solution for 24 hours, then rinsed three times with distilled water, air-dried at room temperature for 12 hours, and placed in sterilized petri plates containing moist filter paper. Fifteen primed seeds per treatment were incubated at 25 ± 2°C, and observations were recorded every 12 hours for one week to evaluate germination and early seedling growth. Data tabulation and parameter calculation were performed using MS Excel, while statistical analysis was conducted in R-studio (version 4.1.1) using the least significant difference (LSD) test at a 5% probability level to compare treatment means.

### Data collection

#### Germination percentage (GP)

It was calculated daily until complete emergence. GP was calculated in percentage using the following formula (Rahman et al 2014):

$$\text{Germination\%} = (\text{Number of germinated seeds} / \text{Total number of seeds used}) \times 100 \dots\dots\dots (1)$$

#### Germination index (GI)

It was calculated using the formula (AOSA 1983)

$$\text{Germination Index (GI)} = \text{Number of germinated seeds} / \text{Days of 1}^{\text{st}} \text{ count} \dots\dots + \text{Number of germinated} / \text{Days of last count} \dots\dots\dots (2)$$

#### Germination energy (GE)

It is defined as the percentage of seeds germinated in 3 days i.e.72hrs (Bam et al 2006). Germination energy is the rapidity of germination and was measured by modifying the formula of (Yan Li, 2008).

$$\text{GE} = \text{No. of total germinated seeds in different priming solutions in 72 hrs} / \text{Total no. of seeds used for germination} \dots\dots\dots (3)$$

#### Measurement of radicle length (RL) and plumule length (PL)

Five samples were randomly selected from each petri plate to measure the overall root (radicle) and plumule length using a vernier caliper and measuring scale (in millimeters).

#### Seedling vigor index (SVI)

It was calculated using the following formula as given by Abdul-Baki and Anderson 1973 and adopted by Dhakal and Subedi 2020, and Gyawali and Subedi 2021.

$$\text{Seedling Vigor Index (SVI)} = \text{Germination (\%)} \times \text{Mean seedling length (mm)} \dots\dots\dots (4)$$

#### Radicle to plumule ratio (R:P)

$$\text{Radicle to plumule ratio} = \text{Length of radicle (mm)} / \text{Length of plumule (mm)} \dots\dots\dots (5)$$

## Statistical Analysis

Data tabulation and parameter calculations was performed using MS Excel, while statistical analysis was carried out using R-studio software (version 4.1.1). The least significant difference (LSD) test was used to separate and compare treatment means at a 5% level of significance.

## RESULTS AND DISCUSSION

### Germination and Seedling Vigor Index

The highest germination percentage was recorded in GA<sub>3</sub> 75 ppm (75.19%) and urea 1% (74.63%), followed by hydro-priming (72.04%) and NaCl 1% (69.41%). The control exhibited the lowest germination (62.23%) (Table 1). The superior germination in GA<sub>3</sub> and urea-treated seeds can be attributed to enhanced water uptake, activation of hydrolytic enzymes, and regulation of hormonal activity, which collectively promote early seedling growth and vigor. Hydro-priming also positively influenced germination, supporting uniform seedling establishment under both optimal and suboptimal conditions. These results are consistent with previous studies reporting that GA<sub>3</sub> and hydro-priming treatments improve germination percentage, seedling vigor index, and reduce mean germination time in cereal crops (Gyawali and Subedi 2021, Singh et al 2022).

**Table 1. Effect of different priming treatments on average germination percentage and average seedling vigor index (12-144 hrs) of maize seeds in Khairahani, Chitwan during 2025.**

Treatments	Average germination %	Average seedling vigor Index (ASVI)
24 hrs hydro-priming	72.04 <sup>ab</sup>	4384.12 <sup>b</sup>
NaCl solution 1%	69.41 <sup>abc</sup>	4046.65 <sup>bc</sup>
Urea solution 0.5%	65.19 <sup>bc</sup>	3115.51 <sup>d</sup>
Urea solution 1%	74.63 <sup>a</sup>	4583.23 <sup>b</sup>
KNO <sub>3</sub> solution 1%	67.22 <sup>abc</sup>	3277.02 <sup>d</sup>
KNO <sub>3</sub> solution 2%	67.60 <sup>abc</sup>	3446.59 <sup>cd</sup>
GA <sub>3</sub> solution 50ppm	62.78 <sup>c</sup>	3224.01 <sup>d</sup>
GA <sub>3</sub> solution 75 ppm	75.19 <sup>a</sup>	5717.14 <sup>a</sup>
Control	62.23 <sup>c</sup>	3288.51 <sup>d</sup>
Grand mean	68.48	3898.09
LSD (0.05)	7.44	667.03
CV %	6.28	9.89
SEm()	2.48	222.49
F-test	*	***

Means with same letter in column shows non-significant difference at p=0.05 by DMRT, \*\*\*\* Significant at 0.001 level of significance (p<0.001), \* Significant at 0.05 level of significance (p<0.05), SEM = standard error of mean, LSD= Least significance difference, CV= Coefficient of variation.

**Table 2. Effect of different priming treatments on radicle length, plumule length and radicle to plumule ratio of maize seeds in Khairahani, Chitwan during 2025.**

Treatments	Radicle length (mm)	Plumule length (mm)	Radicle to plumule ratio
24 hrs hydro-priming	45.95 <sup>b</sup>	6.50 <sup>abc</sup>	7.18
NaCl solution 1%	42.49 <sup>bc</sup>	6.60 <sup>ab</sup>	6.44
Urea solution 0.5%	33.72 <sup>d</sup>	5.41 <sup>bcd</sup>	6.3
Urea solution 1%	47.53 <sup>b</sup>	6.65 <sup>ab</sup>	7.34
KNO <sub>3</sub> solution 1%	34.61 <sup>d</sup>	5.14 <sup>d</sup>	6.75
KNO <sub>3</sub> solution 2%	36.89 <sup>cd</sup>	5.44 <sup>bcd</sup>	6.89
GA <sub>3</sub> solution 50ppm	34.97 <sup>d</sup>	5.22 <sup>cd</sup>	6.71
GA <sub>3</sub> solution 75 ppm	59.39 <sup>a</sup>	7.66 <sup>a</sup>	7.78
Control	33.26 <sup>d</sup>	4.68 <sup>d</sup>	7.11
Grand mean	40.98	5.92	6.95
LSD (0.05)	6.07	1.22	1.83
CV %	8.56	11.94	15.23
SEm	2.02	0.41	0.61
F-test	***	**	NS

Means with same letter in column shows non-significant difference at p=0.05 by DMRT, NS = Non significant \*\*\*\* Significant at 0.001 level of significance (p<0.001), \*\*\* Significant at 0.01 level of significance (p<0.01), SEM = standard error of mean, LSD= Least significance difference, CV= Coefficient of variation.

Seedling vigor index was highest in GA<sub>3</sub> 75 ppm (5717.14), followed by urea 1% (4583.23) and hydro-priming (4384.12), whereas the lowest ASVI was recorded in urea 0.5% (3115.51) (Table 1). Enhanced vigor in GA<sub>3</sub>-treated seeds is likely due to improved enzymatic activity, nutrient mobilization, and hormonal regulation, while

hydro-priming and urea treatments enhance early growth and stress tolerance. These results emphasize the importance of appropriate seed priming techniques for early crop establishment and improved seedling performance (Li et al 2021).

The radicle-to-plumule ratio, an indicator of balanced root and shoot growth, was highest in GA<sub>3</sub> 75 ppm (7.78), followed by urea 1% (7.34) and hydro-priming (7.18). The lowest ratio was observed in urea 0.5% (6.30) (Table 2). Treatments that improved this ratio indicate better coordination between root and shoot development, essential for efficient water and nutrient uptake during early seedling growth (Chaudhary et al 2021, Bhattacharya et al 2022).

### Germination Energy and Index

#### Germination Energy (GE)

The highest GE was observed in seeds primed with urea 1% and GA<sub>3</sub> 75 ppm (76%), which were statistically at par with 24-hour hydro-priming (71.67%) and NaCl 1% (71.33%). The lowest GE was recorded in urea 0.5%, KNO<sub>3</sub> 1%, and GA<sub>3</sub> 50 ppm (67%) (Table 3). The superior performance of urea and GA<sub>3</sub> treatments is likely due to enhanced enzymatic activity, accelerated mobilization of stored reserves, and improved uniformity in seedling emergence. These results are consistent with previous studies demonstrating the positive effect of chemical and hydro-priming on germination under both normal and stress conditions (Nair et al 2021, Sarker et al 2022).

**Table 3. Effect of different priming treatments on germination energy (at 72 hrs) and average germination index (12-144 hrs) of maize seeds in Khairahani, Chitwan during 2025.**

Treatments	Germination energy (GE)	Average germination index (AGI)
24 hrs hydro-priming	71.67	11.73 <sup>ab</sup>
NaCl solution 1%	71.33	11.64 <sup>ab</sup>
Urea solution 0.5%	67	8.57 <sup>bc</sup>
Urea solution 1%	76	13.78 <sup>a</sup>
KNO <sub>3</sub> solution 1%	67	9.74 <sup>bc</sup>
KNO <sub>3</sub> solution 2%	71.67	9.14 <sup>bc</sup>
GA <sub>3</sub> solution 50ppm	67	7.42 <sup>c</sup>
GA <sub>3</sub> solution 75 ppm	76	13.76 <sup>a</sup>
Control	69	5.94 <sup>c</sup>
Grand mean	70.74	10.19
LSD (0.05)	10.74	3.49
CV %	8.76	19.8
SEm(±)	3.58	1.17
F-test	NS	**

Means with same letter in column shows non-significant difference at p=0.05 by DMRT, \*\*\*\* Significant at 0.01 level of significance (p<0.01), NS = Non significant, SEm = standard error of mean, LSD= Least significance difference, CV= Coefficient of variation.

#### Average Germination Index (AGI)

AGI was significantly influenced by seed priming treatments. Urea 1% (13.78) and GA<sub>3</sub> 75 ppm (13.76) exhibited the highest values, followed by 24-hour hydro-priming (11.73) and NaCl 1% (11.64). The lowest AGI was recorded in the control (5.94) and GA<sub>3</sub> 50 ppm (7.42) (Table 3). The enhanced AGI in urea and GA<sub>3</sub> treatments may be attributed to accelerated metabolic activity, improved nutrient mobilization, and enhanced enzymatic activation, facilitating faster and more uniform germination (Chakraborty et al 2022, Onwueme and Chukwuma 2021)

### CONCLUSION

The study showed that seed priming had a positive effect on germination and early seedling growth of maize. From the experiment it was found that GA<sub>3</sub> 75 ppm and urea 1% were superior to other treatments in terms of germination percentage, germination index, radicle and plumule length, radicle to plumule ratio, and seedling vigor index. Likewise, Hydro-priming (24 hrs) and NaCl 1% also enhanced germination and growth, whereas untreated control seeds and low-concentration urea or KNO<sub>3</sub> treatments showed the lowest performance. Thus, GA<sub>3</sub> 75 ppm and urea 1% were suggested as the priming reagent to increase the germination and yield of maize seeds.

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## AUTHORS' CONTRIBUTION

MY Idrishi conducted the lab work, generated and analyzed the data and A Gaire conceptualized and reviewed the manuscript.

## CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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