Received Date: 17 October 2025
Accepted Date: 27 December 2025 **DOI:** https://doi.org/10.3126/jiaas.v39i1.88268

EFFECT OF SEED PRIMING ON GERMINATION AND GROWTH PARAMETERS OF KIDNEY BEAN *(Phaseolus vulgaris L.)*

Prakash Dhungana[1*], Bipin Kumar Neupane[1], Nishchal Pokhrel[1], Deependra Subedi[1], Kiran Puri[1], Nitesh Bhattarai[1], Abhisek Shrestha[1] and Anil Gautam [2]
[1]College of Natural Resource Management, Bardibas, Agriculture and Forestry University, Nepal
[2]Nepal Army Institute of Agriculture Science, Lamjung, Nepal
*Corresponding author: prakashdhungana2057@gmail.com
Prakash Dhungana: 0009-0004-6028-9114
Bipin Kumar Neupane: 0009-0003-9240-2508
Nishchal Pokhrel: 0009-0001-9287-5343
Deependra Subedi: 0009-0000-8014-4853
Kiran Puri: 0009-0001-7368-3151
Nitesh Bhattarai: 0009-0008-0035-8324
Abhisek Shrestha: 0000-0001-7316-3802
Anil Gautam: 000-0002-8491-2554

ABSTRACT

Seed priming is an effective pre-sowing technique to enhance germination, early growth, and stress tolerance in legumes. A field experiment was conducted at the College of Natural Resources Management, Bardibas, Nepal, from December 2023 to April 2024 for evaluating the effects of ten seed priming agents on kidney bean (*Phaseolus vulgaris* L.). Seeds were primed for 12 hours in tap water, untreated control, potassium nitrate (2%), titanium dioxide (2%), cow urine (10%), gibberellic acid (10 ppm), sucrose (10%), calcium oxide (0.1%), glycerol (10%), and magnesium sulphate (0.2%) and sown in a randomized complete block design with four replications. Significant differences were observed among treatments for germination, plant height, secondary branching, days to 50% flowering, and field survival by using R-Studio. Titanium dioxide (2%) achieved the highest germination (99.38%), calcium oxide (0.1%) produced maximum plant height (11.18 cm), earliest flowering (35 days), and the highest survival (37 plants plot^{-1}), while gibberellic acid (10 ppm) enhanced secondary branching (5 branches plant^{-1}). These results indicate that calcium oxide and titanium dioxide are most effective for improving early growth and stress tolerance, and gibberellic acid promotes branching. However, the study did not assess the effects of these priming agents on final yield, nutrient content, or long-term stress resilience, highlighting the need for multi-season and multi-location trials to evaluate their impact on productivity and crop performance under varying environmental conditions.

Key words: *Germination, field tolerance, kidney bean, priming, titanium dioxide*

INTRODUCTION

Kidney bean (*Phaseolus vulgaris* L.) is an economically and nutritionally important grain legume, valued for its high protein content, dietary fiber, and low-glycemic carbohydrates such as resistant and slowly digestible starches (Coyne et al., 2020). In Nepal, kidney bean is cultivated across a wide range of agro-ecological zones; however, national productivity remains relatively low due to poor seed quality, uneven germination, and weak early crop establishment, particularly under stress-prone environments (Dhakal, 2020; MoALD, 2024). Early growth stages are critical for determining plant survival, canopy development, and flowering behavior, making improvement of germination and early vegetative performance a major production challenge.

Seed priming is a simple and low-cost pre-sowing technique that involves controlled hydration of seeds to initiate metabolic activities without radicle emergence, resulting in faster and more uniform germination after sowing (Tiwari et al., 2013). Inorganic priming agents such as potassium nitrate and gibberellic acid have been shown to influence early seedling growth and branching, while calcium-based compounds play an important role in maintaining membrane integrity and mitigating stress during early growth stages (Sundharan & Kamaraj, 2024)

Recent advancements in seed priming research have highlighted the potential of nano-priming approaches, particularly titanium dioxide nanoparticles, which have been reported to enhance germination efficiency, antioxidant activity, and early seedling growth in *Phaseolus vulgaris* under controlled and field conditions(Alabdallah et al., 2024). These studies suggest that novel priming materials, in addition to conventional agents, may offer effective strategies for improving early crop establishment under suboptimal environments.

Despite the availability of studies on seed priming, much of the existing literature primarily emphasizes yield and yield-attributing traits, while limited attention has been given to early vegetative parameters such as leaf development, secondary branching, flowering initiation, and field survival under natural stress conditions. Moreover, comparative field-based evaluations of conventional priming agents alongside emerging materials such as calcium oxide and titanium dioxide under Nepalese agro-climatic conditions remain scarce. This lack of information restricts a clear understanding of how seed priming influences early plant architecture and stress adaptation prior to yield formation.

Early growth traits, including germination percentage, plant height, leaf number, secondary branching, and days to flowering, are key determinants of crop establishment and resilience, particularly in environments prone to drought, heat, and biotic stresses. Evaluating these parameters provides a strong physiological basis for identifying effective priming agents before progressing to yield-focused investigations. Therefore, the present study was undertaken to assess the effects of ten seed priming agents on germination, early vegetative growth, leaf and branch development, flowering behaviour up to 50% flowering, and field survival of kidney bean under natural field stress conditions. The findings aim to identify suitable priming treatments for improving early crop performance and to generate reliable baseline information for future yield-oriented research.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the Field of College of Natural Resources Management, Bardibas-6, Mahottari, Nepal, during the period from December 2023 to April 2024. The experimental site is located at 26°56′37″ N latitude and 85°53′26″ E longitude, with an altitude of approximately 189 masl. The area experiences a subtropical climate. During the experimental period, the average maximum and minimum temperatures were approximately 27.9 °C and 15.6 °C, respectively, with relative humidity ranging from 60% to 80% (DHM, 2023). The soil of the experimental field was sandy loam in texture, slightly acidic (pH 5.8–6.5), well drained, and moderate in organic matter content, as reported by the Ministry of Agriculture and Livestock Development (MoALD, 2024).

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) comprising ten seed priming treatments, each replicated four times, resulting in a total of forty experimental plots. Each plot measured 2 m × 2 m and consisted of five rows. Row-to-row spacing was maintained at 40 cm, while plant-to-plant spacing was 25 cm to ensure uniform crop stand and optimum plant population.

Table 1. Ten seed priming treatments

T_1: Tap water
T_2: Untreated control
T_3: Potassium nitrate (KNO_3) @ 2%
T_4: Titanium dioxide (TiO_2) @ 2%
T_5: Cow urine @ 10%
T_6: Gibberellic acid (GA_3) @ 10 ppm
T_7: Sucrose @ 10%
T_8: Calcium oxide (CaO) @ 0.1%
T_9: Glycerol @ 10%
T_{10}: Magnesium sulphate ($MgSO_4$) @ 0.2%

Seed priming procedure

Healthy and uniform seeds of kidney bean (*Phaseolus vulgaris* L.) were selected prior to priming. Seeds for each treatment were soaked in their respective priming solutions for 12 hours at room temperature. The seed-to-solution ratio was maintained at 1:5 (w/v) to ensure uniform hydration. After soaking, seeds were removed from the solutions, thoroughly rinsed with distilled water (except control and tap water treatments), and shade-dried on blotting paper until they reached their original moisture content suitable for sowing. Untreated control seeds were sown without any priming.

Land preparation and crop management

The experimental field was ploughed twice and levelled properly before sowing. Well-decomposed farmyard manure (FYM) was incorporated into the soil at the rate of 15 t ha^{-1} during final land preparation. Chemical fertilizers were applied at the recommended rate of 80:120:60 kg N:P:K ha^{-1}, using urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). The full dose of phosphorus and potassium and half of the nitrogen were applied as a basal dose at sowing, while the remaining nitrogen was top-dressed after the first irrigation.

Sowing was carried out manually using line sowing. Standard agronomic practices such as irrigation, manual weeding, and plant protection measures were followed uniformly across all treatments throughout the cropping period.

Data collection

Observations were recorded on the following parameters:

- Germination percentage: Calculated on a plot basis by counting the number of emerged seedlings seven days after sowing.
- Plant height (cm): Measured from the soil surface to the apical tip at 15 and 30 days after sowing using a measuring scale.
- Number of leaves per plant: Counted from randomly selected plants at 15 and 30 days after sowing.
- Number of secondary branches: Recorded at the vegetative stage from selected plants in each plot.
- Days to 50% flowering: Calculated as the number of days from sowing to the date when 50% of plants in a plot showed flowering.

Field survival: Determined by counting the number of surviving plants per plot under naturally occurring stress conditions, including drought (withholding irrigation during critical stages), heat stress (>35 °C during March–April), and biotic stress such as yellow vein mosaic virus.

Statistical analysis

All recorded data were first compiled and organized using Microsoft Excel. Statistical analyses were performed using R-Studio software, employing the agricolae package for agricultural data analysis. Analysis of variance (ANOVA) was conducted to test the significance of treatment effects under a randomized complete block design (RCBD) at the 5% level of significance ($p \leq 0.05$). When ANOVA indicated significant differences among treatments, Duncan's Multiple Range Test (DMRT) was applied for post-hoc mean separation using the *agricolae* package. Treatment means were compared and grouped based on significant differences, and results were expressed as mean values with appropriate statistical groupings.

RESULTS AND DISCUSSION

Germination percentage

Table 2: Germination percentage as affected by seed priming at Bardibas, Nepal, 2024

Treatment	Germination (%)
Tap water	95.63^{b}
Untreated control	80.12^{d}
Potassium nitrate (2%)	48.75^{f}
Titanium dioxide	99.38^{a}
Sodium chloride	67.88^{e}
Gibberellic acid	88.25^{c}
Hydrogen peroxide	91.45^{c}
Calcium oxide	97.82^{a}
Glycerol	92.67^{bc}
Magnesium sulphate	90.34^{c}
F-test	*
LSD (0.05)	1.21
CV (%)	7.85
Grand mean	85.23

*Note- LSD: Least Significant Difference; SEm: Standard error of means; CV: Coefficient of variance; * denotes significance; Treatment means followed by the same letter(s) are a non-significant difference on the Duncan multiple range test at the 0.05 level of significance.*

Seed priming treatments significantly influenced the germination percentage of the kidney bean. Among the treatments, titanium dioxide recorded the highest germination (99.38%), followed by calcium oxide (97.82%) and tap water (95.63%), indicating enhanced seed metabolic activation and improved water uptake. The untreated control showed comparatively lower germination (80.12%), confirming the advantage of priming over non-primed seeds. In contrast, potassium nitrate (48.75%) and sodium chloride (67.88%) significantly reduced germination, likely due to osmotic stress and ionic toxicity that interfered with seed hydration and enzymatic activity. Similar enhancement of germination through nano-priming with titanium dioxide has been reported in *Phaseolus vulgaris* by Alabdallah et al., (2024), who attributed the effect to increased enzyme activity and membrane stability.

Table 3: Average plant height, leaves and secondary branches as affected by seed priming at Bardibas, Nepal, 2024

Treatment	Average		
	Plant height (cm)	**Leaves plant^{-1}**	**Secondary branches plant^{-1}**
Tap water	10.20^{cd}	3.8	4.2^{cd}
Untreated control	10.10^{cd}	3.6	4.4^{cd}
Potassium nitrate	9.50^{de}	3.5	4.5^{bc}
Titanium dioxide	10.80^{b}	3.7	4.8^{ab}
Sodium chloride	9.00^{e}	3.3	3.6^{e}
Gibberellic acid	8.20^{f}	3.2	5.0^{a}
Hydrogen peroxide	10.50^{bc}	3.7	4.7^{ab}
Calcium oxide	11.18^{a}	3.4	3.6^{e}
Glycerol	10.90^{ab}	3.5	4.3^{cd}
Magnesium sulphate	10.40^{bc}	3.8	4.6^{bc}
F-test	*	NS	*
LSD (0.05)	0.19	0.07	0.15
CV (%)	8.42	6.15	9.72
Grand mean	10.08	3.55	4.37

*Note- LSD: Least Significant Difference; SEm: Standard error of means; CV: Coefficient of variance; * denotes significance; NS: Non-significant. Treatment means followed by the same letter(s) are a non-significant difference on the Duncan multiple range test at the 0.05 level of significance.*

Plant height

Plant height differed significantly among treatments at early growth stages. Calcium oxide produced the tallest plants (11.18 cm), followed by glycerol (10.9 cm) and titanium dioxide (10.8 cm), indicating improved cell elongation and nutrient assimilation. Calcium-based priming agents are known to enhance cell wall strength and regulate hormonal balance, which may explain the superior vegetative growth observed. Gibberellic acid and sodium chloride resulted in comparatively shorter plants, suggesting possible diversion of assimilates towards branching or stress-induced growth suppression. These findings are consistent with earlier reports highlighting the role of calcium compounds in improving early vegetative vigor under field conditions (Mazhar et al., 2022).

Number of leaves

The average number of leaves per plant ranged from 3.2 to 3.8 across treatments and did not significantly affect early leaf number, indicating that leaf initiation during early growth is relatively stable and less responsive to pre-sowing treatments. Similar observations have been reported in legumes where seed priming improved germination and seedling vigor but showed no significant influence on early leaf number, suggesting that leaf initiation is predominantly under genetic control rather than external seed treatments (Wang & Li, 2008). Although leaf count remained unaffected, qualitative improvements in plant vigor were evident in other growth parameters.

Secondary branch development

Secondary branching was significantly influenced by seed priming treatments. Gibberellic acid recorded the highest number of secondary branches (5.0 branches plant^{-1}), followed by titanium dioxide and hydrogen peroxide. Gibberellic acid is known to stimulate axillary bud development and internodal elongation, which may have contributed to enhanced branching. Conversely, calcium oxide and sodium chloride recorded fewer branches, suggesting a growth pattern favoring vertical elongation over lateral expansion. These results agree with De et al. (2024), who reported increased branching in legumes following GA_3 application. The variation in branching highlights the importance of selecting priming agents based on desired plant architecture.

Table 4: Days to 50% flowering and survival capacity as affected by seed priming at Bardibas, Nepal, 2024

Treatment	Days to 50% flowering	Surviving plants plot^{-1} after observing stress and disease
Tap water	37.0^{a}	28de
Untreated control	36.7^{ab}	30^{cd}
Potassium nitrate	36.5^{bc}	26^{e}
Titanium dioxide	35.8^{cd}	33^{bc}
Sodium chloride	36.2^{bc}	13^{f}
Gibberellic acid	36.0^{bc}	31^{cd}
Hydrogen peroxide	35.5^{de}	32^{bc}
Calcium oxide	35.0^{e}	37^{a}
Glycerol	35.2^{de}	34^{b}
Magnesium sulphate	35.6^{cd}	36^{ab}
F-test	*	*
LSD (0.05)	0.28	1.42
CV (%)	5.21	11.38
Grand mean	35.95	30

*Note- LSD: Least Significant Difference; SEm: Standard error of means; CV: Coefficient of variance; *denotes significance; Treatment means followed by the same letter(s) are a non-significant difference on the Duncan multiple range test at the 0.05 level of significance.*

Days to 50% flowering

Days to 50% flowering varied significantly among seed priming treatments. Calcium oxide induced the earliest flowering (35 days), followed by glycerol and magnesium sulphate, suggesting that these treatments improved physiological efficiency and accelerated the transition from the vegetative to the reproductive phase. In contrast, control and tap water treatments showed delayed flowering, indicating less favorable internal conditions for floral induction. Similar trends have been observed in seed priming studies where calcium chloride priming significantly reduced the days to 50% flowering compared to the control, indicating a shift toward earlier reproductive development in response to priming agents (Rout et al., 2025) Early flowering induced by calcium-based and nano-priming agents may be associated with improved photosynthetic efficiency and hormonal regulation, promoting quicker accumulation of assimilates and triggering floral pathways. Since flowering time is a critical adaptive trait, earlier flowering can confer a competitive advantage under stress-prone environments by enabling plants to complete reproduction before adverse conditions intensify.

Field survival

Field survival differed markedly among treatments under natural abiotic and biotic stress conditions. Calcium oxide recorded the highest survival (37 plants plot^{-1}), followed by magnesium sulphate and glycerol, reflecting enhanced stress tolerance and better root–soil interaction. Titanium dioxide also showed high survival, supporting its role in improving antioxidant defense mechanisms. Sodium chloride resulted in the lowest survival (13 plants), reaffirming its detrimental effects on plant establishment. Improved survival due to calcium- and nano-based priming has been previously linked to enhanced membrane stability and stress buffering capacity(Mazhar et al., 2023).

CONCLUSION

This study evaluated the effect of ten seed priming agents on germination, early growth, branching, flowering, and field survival of kidney bean (Phaseolus vulgaris L.) under field conditions at Bardibas, Nepal. Seeds were primed for 12 hours in solutions including tap water, untreated control, potassium nitrate (2%), titanium dioxide (2%), cow urine (10%), gibberellic acid (10 ppm), sucrose (10%), calcium oxide (0.1%), glycerol (10%), and magnesium sulphate (0.2%), and then sown in a randomized complete block design with four replications. The results showed significant variation among treatments. Titanium dioxide (2%) priming produced the highest germination (99.38%), demonstrating enhanced metabolic activation and water uptake. Calcium oxide (0.1%) resulted in the tallest plants (11.18 cm), earliest 50% flowering (35 days), and the highest field survival (37 plants plot^{-1}), indicating improved physiological efficiency and stress tolerance. Gibberellic acid (10 ppm) significantly increased secondary branching (5 branches plant^{-1}), promoting lateral growth. In contrast, potassium nitrate (2%) and sodium chloride negatively affected germination and survival due to osmotic and ionic stress. Leaf number (3.2–3.8 leaves plant^{-1}) was not significantly influenced by priming treatments, suggesting that early leaf development is largely genetically controlled. Overall, calcium oxide and titanium dioxide were the most effective priming agents for enhancing early vegetative vigor, stress tolerance, and crop establishment, while gibberellic acid improved branching architecture. These findings provide a strong basis for selecting suitable seed priming treatments for kidney bean and highlight their potential to improve early growth and survival under field stress conditions. These research only observed the early response and most of the plant are suffered by Yellow vein mosaic virus so yield data was not observed so future research should focus on evaluating their impact on final yield and yield components.

ACKNOWLEDGEMENTS

The authors would like to thank the College of Natural Resource Management (CNRM), Bardibas family for providing the needed resources, the 3rd batch of CNRM Bardibas and our juniors Mr. Rishi Raj Ghimire, Mr. Nawaraj Yadav and Mr. Pradip Adhikari, for extending their helping hands during the experiment

REFERENCES

Alabdallah, N. M., Alluqmani, S. M., Almarri, H. M., & AL-Zahrani, A. A. (2024). Physical, chemical, and biological routes of synthetic titanium dioxide nanoparticles and their crucial role in temperature stress tolerance in plants. *Heliyon*, *10*(4), e26537. https://doi.org/10.1016/j.heliyon.2024.e26537

Coyne, C. J., Kumar, S., Von Wettberg, E. J. B., Marques, E., Berger, J. D., Redden, R. J., Ellis, T. H. N., Brus, J., Zablatzká, L., & Smýkal, P. (2020). Potential and limits of exploitation of crop wild relatives for pea, lentil, and chickpea improvement. *Legume Science*, *2*(2), e36. https://doi.org/10.1002/leg3.36

De, P., Bahadur, V., & Topno, S. E. (2024). Effect of Gibberellic Acid and Cytokinin on Growth, Quality and Yield of French Bean (Phaseolus vulgaris L.) cv. Ellora No. 11. *Journal of Experimental Agriculture International*, *46*(5), 538–545. https://doi.org/10.9734/jeai/2024/v46i52408

Department of Hydrology and Meteorology (DHM). (2024). *Annual climate summary of Nepal 2023*. Government of Nepal, Ministry of Energy, Water Resources and Irrigation.

Dhakal, A. (2020). PRESENT STATUS OF GRAIN LEGUMES PRODUCTION IN NEPAL. *Food & Agribusiness Management*, *2*(1), 06–09. https://doi.org/10.26480/fabm.01.2021.06.09

Mazhar, M. W., Ishtiaq, M., Maqbool, M., Atiq Hussain, S., Casini, R., Abd-ElGawad, A. M., & Elansary, H. O. (2023). Seed Nano-Priming with Calcium Oxide Maintains the Redox State by Boosting the Antioxidant Defense System in Water-Stressed Carom (Trachyspermum ammi L.) Plants to Confer Drought Tolerance. *Nanomaterials*, *13*(9), 1453. https://doi.org/10.3390/nano13091453

Ministry of Agriculture and Livestock Development (MoALD). (2024). *Statistical information on Nepalese agriculture 2023/24*. Government of Nepal.

Rout, A., Kulkarni, C. C., Monalisa, S. P., Mishra, S., Tripathy, S., & Swain, S. K. (2025). Influence of Seed Priming on Morphological Parameters in Groundnut (Arachis hypogea L.). *Agricultural Science Digest - A Research Journal*, *Of*. https://doi.org/10.18805/ag.D-6187

Sundharan, M., & Kamaraj, A. (2024). Effect of Seed Priming Using GA3, KNO3, ZnSO4 on Germination Parameters of Vigna unguiculata. *Environment and Ecology*, *42*(4), 1552–1561. https://doi.org/10.60151/envec/WTVF2933

Tiwari, T. N., KAMAL, D., Kumar, V., Chaturvedi, A. K., & Prasad, S. R. (2013). Relative efficacy of in-organic salts as priming agent on germination, vigour, nitrate assimilation and yield in mungbean. *Seed Research*, *41*(2), 180-189.

Wang, Y., & Li, J. (2008). Molecular Basis of Plant Architecture. *Annual Review of Plant Biology*, *59*(1), 253–279. https://doi.org/10.1146/annurev.arplant.59.032607.092902