



OPTIMIZING HYDROPRIMING DURATION FOR PIGEONPEA (*CAJANUS CAJAN* (L.) MILLSP.) SEED GERMINATION AND VIGOUR

Ankita Vishwakarma, Tulika Mishra*

Department of Botany, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India.



***Corresponding Author: Tulika Mishra**

Department of Botany, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India.

DOI: <https://doi.org/10.5281/zenodo.22253513>

How to cite this Article: Ankita Vishwakarma, Tulika Mishra*. (2026). Optimizing hydropriming duration for pigeonpea (*cajanus cajan* (L.) Millsp.) Seed germination and vigour. European Journal of Biomedical and Pharmaceutical Sciences, 13(9), 252–259.

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Article Received on 05/08/2026

Article Revised on 25/08/2026

Article Published on 02/09/2026

ABSTRACT

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is an important nutraceutical legume of the Indian subcontinent, valued for its rich content of proteins, dietary fibre, minerals and bioactive phenolic compounds, but its field productivity remains low owing to poor seed germination, delayed seedling emergence and weak seedling vigour. Seed priming, particularly hydropriming, is a simple, low-cost and eco-friendly pre-sowing treatment reported to improve crop establishment in several pulse crops. The present investigation was undertaken to evaluate the effect of hydropriming duration on seed germination and early seedling growth of *Cajanus cajan*. Surface-sterilized seeds were hydroprimed by soaking in sterile distilled water for 6, 12 and 24 hours (T2, T3 and T4, respectively) and compared with untreated control seeds (T1) in a Completely Randomized Design with three replications. Germination percentage, mean germination time, germination index, seed vigour index, root length, shoot length and allometric index were recorded. Hydropriming significantly improved all germination and seedling growth parameters relative to the control. The 12-hour hydropriming treatment (T3) produced the highest germination percentage (9.53%), germination index (3.75) and seed vigour index (47.07), the greatest root length (4.20 cm) and shoot length (4.73 cm), and the shortest mean germination time (2.47 days), while the allometric index (1.33) remained unchanged across all treatments, indicating balanced root–shoot growth. These findings demonstrate that hydropriming for 12 hours is the most effective duration for enhancing seed vigour and seedling establishment in pigeon pea and can be recommended as a practical, low-input seed-enhancement technique for improving crop stand under rainfed and marginal farming conditions.

KEYWORDS: *Cajanus cajan*, pigeon pea, hydropriming, seed priming, seed germination, seedling vigour index.

1. INTRODUCTION

Plant-derived secondary metabolites have been employed in medicine for therapeutic applications since time immemorial, and the early evolution of modern medicine highlights the use of plant-derived phytochemicals, many

of which remain therapeutically relevant today. *Cajanus cajan* (L.) Millsp., known as Adhaki (Sanskrit), Arhar (Hindi), Pigeon pea (English) and Tur (Bengali), represents one such medicinally and nutritionally important leguminous species (Figure 1) (24).



Figure 1: Plant and seeds of *Cajanus cajan* (24).

Pigeon pea is an ancient leguminous crop whose cultivation dates back nearly 3000 years and is believed to have originated in Asia before spreading to East Africa and the Americas. Despite its long history and wide geographical distribution, pigeon pea still shows comparatively low productivity in India; it is cultivated over approximately 4.65 million hectares with a production of 3.02 million tonnes and an average productivity of only 700 kg ha⁻¹.^[24, 34]

To overcome the problems associated with poor germination, delayed seedling emergence and low seedling vigour, various seed-enhancement techniques have been developed to improve crop establishment and productivity. Among these, hydropriming — a form of seed priming — has gained considerable attention as an effective, economical and environmentally friendly approach. The concept of seed priming was first introduced by Heydecker in 1973.^[19]

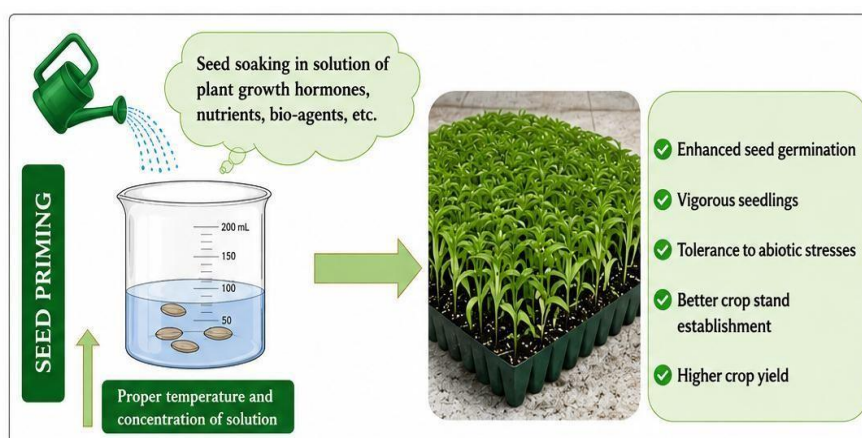


Figure 2: Effect of seed priming on germination, seedling vigour and crop establishment.^[1]

Several seed-priming methods have since been developed to enhance seed quality and crop performance, including hydropriming, halopriming, osmopriming, matrix priming, on-farm priming, hormonal or growth-regulator priming, micronutrient priming (nutripriming), biopriming with beneficial microorganisms such as *Pseudomonas aureofaciens* and *Trichoderma sp.*, and nanoparticle priming. The effectiveness of each method varies among crops and requires optimization for individual species and cultivars, depending on treatment duration, the priming agent used, seed vigour and storage conditions such as temperature, moisture content and oxygen availability.^[28]

Objectives of the Study

1. To evaluate the effect of hydropriming on seed germination in *Cajanus cajan*.
2. To study seedling vigour after hydropriming treatment.

3. To analyse the physiological effects of hydropriming on seed performance.

Beyond its agronomic relevance, pigeon pea is a valuable nutraceutical crop with diverse health-promoting properties. Its richness in proteins, dietary fibres, minerals, vitamins, flavonoids, phenolics and antioxidant compounds contributes significantly to its medicinal and therapeutic potential, with reported antioxidant, antidiabetic, anti-inflammatory, antimicrobial, cardioprotective and hepatoprotective activities that support its use as a functional food and nutraceutical ingredient.

Seed Priming as a Conservation Technique

Seed priming is an important pre-sowing treatment that enhances seed germination, seedling establishment and crop performance under normal as well as stress conditions.^[18,16] In recent years it has gained

considerable attention as a sustainable, low-cost conservation technique because it improves seed vigour, reduces seedling mortality and helps crops tolerate adverse environmental conditions such as drought, salinity and temperature stress.^[29] In crops such as pigeon pea, seed priming is particularly important for improving early growth and achieving better plant establishment under rainfed and marginal farming conditions.^[18]

Seed priming involves controlled hydration of seeds before sowing, allowing the early stages of germination metabolism to occur without radicle emergence; seeds are then re-dried to their original moisture level before sowing. This activates several physiological and biochemical processes that enhance rapid and uniform germination.^[1] Among the various priming methods, hydropriming is considered the simplest, cheapest and most eco-friendly technique, requiring only water for seed soaking.^[1]

Seed priming is widely recognized as a conservation technique because it supports sustainable crop production while minimizing external chemical inputs.^[16] Primed seeds generally exhibit faster emergence and better root development, which improves water and nutrient uptake efficiency and enhances drought tolerance during early growth stages.^[18] In semi-arid and tropical regions where pigeon pea is mostly cultivated, water scarcity and erratic rainfall often reduce germination and crop establishment; hydropriming helps conserve soil moisture by promoting quick and synchronized seedling emergence.^[29]

Several recent studies report that seed priming enhances physiological activities such as enzyme activation, protein synthesis, DNA repair and antioxidant metabolism.^[1,16] During priming, hydrolytic enzymes such as amylase and protease are activated, breaking down stored food reserves into simpler compounds that are readily utilised during germination, thereby accelerating germination and promoting uniform seedling growth.^[18] Primed seeds also exhibit enhanced membrane stability and improved antioxidant defence systems that protect seedlings from oxidative damage under stress conditions.^[16]

Hydropriming has shown positive effects on pulse crops and legumes, especially under unfavourable environmental conditions. In pigeon pea, hydropriming

improves germination percentage, seedling vigour, root length, shoot length and biomass accumulation,^[9] with faster germination in primed seeds resulting in better field establishment and early crop growth that ultimately contributes to improved productivity. Improved seed vigour obtained through hydropriming is particularly beneficial in rainfed agriculture, where rapid seedling establishment is necessary for better crop survival.

2. MATERIALS AND METHODS

2.1 Collection of Plant Material

Healthy and mature seeds of *Cajanus cajan* were collected from the campus of Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India.

2.2 Seed Surface Sterilization

1. Seeds were washed under running tap water for 15–20 minutes.
2. Seeds were treated with 1–2% Tween-20 for 5–10 minutes.
3. Surface sterilization was carried out using 0.1% HgCl_2 for 1–2 minutes.
4. Seeds were rinsed 3–4 times with sterile distilled water.

2.3 Seed Priming Treatment

Seeds were soaked in sterile distilled water for 6, 12 and 24 hours at room temperature; unprimed seeds served as the control. After soaking, seeds were shade-dried for 5–6 hours to regain their original moisture content before sowing.

2.4 Experimental Setup

The experiment was conducted under laboratory conditions to evaluate the effect of hydropriming on seed germination and seedling growth of *Cajanus cajan*. Healthy, uniform and surface-sterilized seeds were used. The experiment consisted of four treatments — one control (T1, untreated) and three hydropriming treatments in which seeds were soaked in distilled water for 6 hours (T2), 12 hours (T3) and 24 hours (T4). After soaking, seeds were surface-dried gently with blotting paper and placed in Petri plates lined with moist filter paper for germination under suitable laboratory conditions. The experiment was laid out in a Completely Randomized Design (CRD) with three replications per treatment, and observations were recorded regularly throughout the experimental period (Table 1).

Table 1: Experimental setup.

Treatment	Details	Duration	Replications
T1	Control	Untreated	3
T2	Hydropriming	6 hrs	3
T3	Hydropriming	12 hrs	3
T4	Hydropriming	24 hrs	3

The parameters studied included germination percentage, germination index, mean germination time, root length, shoot length, seed vigour index and allometric index

(Table 2). The data were analysed to determine the influence of hydropriming treatments on germination performance and seedling development of *Cajanus cajan*.

Table 2: Parameters observed during the experimental study.

S. No.	Parameter Observed
1	Germination Percentage (%)
2	Germination Index
3	Mean Germination Time (days)
4	Root Length (cm)
5	Shoot Length (cm)
6	Seed Vigour Index
7	Allometric Index

2.5 Germination Procedure

The germination test was carried out under controlled laboratory conditions using sterilized Petri plates lined with moist filter paper. After hydropriming, seeds were surface-dried and evenly placed in the Petri plates, and adequate moisture was maintained throughout the experiment by adding distilled water as required. For each treatment, seeds were arranged separately with three replications and maintained at room temperature. Daily observations were taken to record the emergence of radicle and plumule, and seed germination was evaluated on the basis of normal seedling emergence.

2.6 Statistical Analysis

The experimental data obtained from the different treatments were analysed to evaluate the effect of hydropriming on seed germination and seedling growth parameters of *Cajanus cajan*. All observations were recorded in triplicate and mean values were calculated

for each parameter. Comparative analysis among treatments was performed to determine variations in germination and growth performance.

3. RESULTS AND DISCUSSION

3.1 Effect of Hydropriming on Germination Percentage and Mean Germination Time

Hydropriming treatments had a noticeable influence on seed germination and seedling establishment of *Cajanus cajan*, with clear variation among treatments in germination percentage and mean germination time (Table 3, Figure 3). Among all treatments, T3 (12-hour hydropriming) showed the highest germination percentage (9.53%), whereas the control (T1) recorded the lowest (7.93%); T2 (6 hours) and T4 (24 hours) also showed improved germination of 8.71% and 9.11%, respectively. This improvement may be attributed to enhanced water absorption and activation of metabolic processes inside the seed prior to germination.

Table 3: Effect of hydropriming on germination percentage, mean germination time, germination index and seed vigour index of *Cajanus cajan*.

Treatment	Germination (%)	Mean Germination Time (days)	Germination Index	Seed Vigour Index
T1 (Control)	7.93	5.11	2.53	32.03
T2 (6 hrs)	8.71	2.81	3.11	38.61
T3 (12 hrs)	9.53	2.47	3.75	47.07
T4 (24 hrs)	9.11	2.64	3.39	42.90

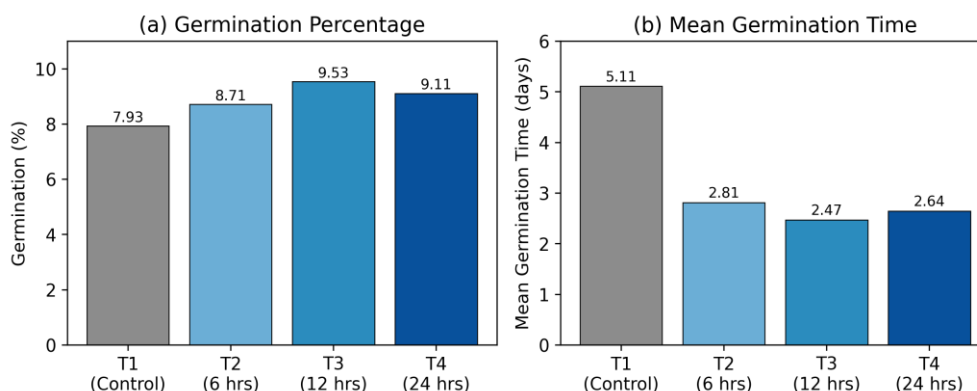


Figure 3: Effect of hydropriming duration on (a) germination percentage and (b) mean germination time of *Cajanus cajan*.

Mean germination time was also affected by hydropriming: untreated control seeds required a longer duration to germinate (5.11 days), whereas hydroprimed seeds showed a reduced mean germination time, the lowest being recorded in T3 (2.47 days), followed by T4 (2.64 days) and T2 (2.81 days). This reduction indicates that hydropriming accelerated the physiological activities associated with germination, most likely through improved seed hydration and faster enzymatic activity leading to earlier seedling emergence. The results clearly demonstrate that hydropriming positively influenced germination behaviour in *Cajanus cajan*, with the 12-hour treatment showing comparatively superior performance.

3.2 Effect of Hydropriming on Germination Index and Seed Vigour Index

Significant improvement was observed in both germination index and seed vigour index under hydropriming as compared to untreated seeds (Table 3, Figure 4). The highest germination index was recorded in T3 (3.75), followed by T4 (3.39) and T2 (3.11), while the control showed the lowest value (2.53), indicating improved speed and uniformity of germination in hydroprimed seeds, possibly through better activation of enzymatic systems and mobilization of stored food materials.

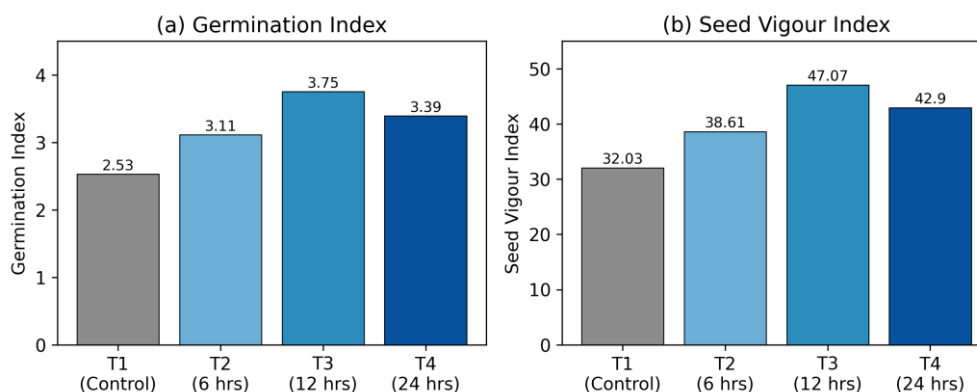


Figure 4: Effect of hydropriming duration on (a) germination index and (b) seed vigour index of *Cajanus cajan*.

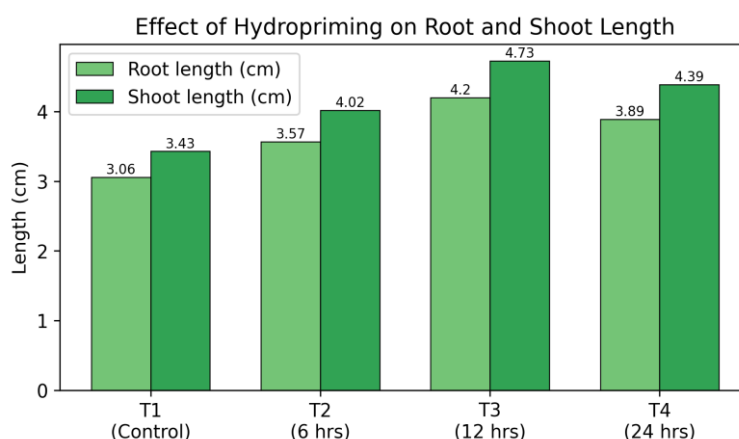
Similarly, seed vigour index showed considerable improvement due to hydropriming, with the maximum value observed in T3 (47.07), followed by T4 (42.90) and T2 (38.61), while the control recorded the minimum (32.03). Increased seed vigour index reflects healthier and more vigorous seedling production under hydropriming, possibly through improved membrane permeability and metabolic repair during imbibition. Notably, hydropriming beyond 12 hours (i.e., 24 hours) produced comparatively lower seed vigour than the 12-hour treatment, suggesting that excessive soaking duration does not confer additional benefit and may even be counter-productive.

3.3 Effect of Hydropriming on Root Length and Shoot Length

Root and shoot length, both important indicators of seedling growth and establishment, were positively affected by hydropriming (Table 4, Figure 5). The highest root length was observed in T3 (4.20 cm), followed by T4 (3.89 cm) and T2 (3.57 cm), while the control showed the lowest root length (3.06 cm). This may be attributed to early activation of cell division and elongation during germination; a well-developed root system enhances water and nutrient uptake, supporting better overall plant growth.

Table 4: Effect of different hydropriming treatments on root length, shoot length and allometric index of *Cajanus cajan* seedlings.

Treatment	Root Length (cm)	Shoot Length (cm)	Allometric Index
T1 (Control)	3.06	3.43	1.33
T2 (6 hrs)	3.57	4.02	1.33
T3 (12 hrs)	4.20	4.73	1.33
T4 (24 hrs)	3.89	4.39	1.33

**Figure 5: Effect of hydropriming duration on root and shoot length of *Cajanus cajan* seedlings.**

Shoot length also increased significantly under hydropriming, with the maximum recorded in T3 (4.73 cm), followed by T4 (4.39 cm) and T2 (4.02 cm), while the minimum was observed in the control (3.43 cm). Enhanced shoot growth may be associated with improved mobilization of seed reserves and rapid seedling emergence following hydropriming. The 12-hour treatment proved most effective overall, suggesting that an optimum soaking duration is essential for maximum seedling growth benefit, as excessive soaking may lead to oxygen deficiency or overhydration that reduces seedling performance.

3.4 Effect of Hydropriming on Allometric Index

The allometric index remained comparatively stable across all treatments, with a recorded value of 1.33 in every treatment including the control (Table 4). This uniformity suggests that although hydropriming significantly improved root and shoot length, the proportional relationship between root and shoot growth remained balanced, indicating that hydropriming promoted overall seedling development without disturbing the natural growth ratio between underground and aboveground plant parts — an important attribute for proper seedling establishment and subsequent plant development.

Collectively, the results indicate that hydropriming treatments improved seed germination and seedling growth characteristics of *Cajanus cajan*, with 12 hours of hydropriming showing the best overall performance with respect to germination percentage, germination index, seed vigour index, root length and shoot length.

4. CONCLUSION

The present study demonstrated that hydropriming had a positive effect on seed germination and seedling growth of *Cajanus cajan*. Different hydropriming durations significantly influenced germination behaviour, seed vigour and seedling development compared with untreated seeds. Among all treatments, hydropriming for 12 hours (T3) proved to be the most effective, showing the highest germination percentage, germination index, seed vigour index, root length and shoot length, along with the shortest mean germination time. These findings indicate that hydropriming enhanced water uptake and activated the metabolic processes responsible for faster and more uniform germination, producing healthier and more vigorous seedlings than untreated seeds. The allometric index remained constant across treatments, indicating balanced seedling growth under hydropriming. Overall, the study concludes that hydropriming can be effectively used to improve germination and early seedling establishment in *Cajanus cajan*, particularly at a 12-hour priming duration, and represents an efficient, economical and simple seed-enhancement technique suitable for rainfed and marginal farming conditions. Further studies under field conditions are recommended to evaluate the long-term effects of hydropriming on plant growth and yield performance.

ACKNOWLEDGEMENT

The author gratefully acknowledges the Department of Botany, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India, for providing the laboratory facilities necessary to carry out this study.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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