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The Effect of Nutri-Priming in Revolutionising Germination and Seedling Vigour in Green gram: Unleashing Seed Power

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ABSTRACT

Seed priming had a distinct, concentration-dependent effect on the germination and early growth of green gram (Vigna radiata L., cv. Samrat). Nutri-priming solutions were prepared using digested banana stems at concentrations of 0.00 mL (T_1), 0.25 mL (T_2), 0.50 mL (T_3), 1.00 mL (T_4), 2.00 mL (T_5), 3.00 mL (T_6), and 4.00 mL (T_7), diluted in 15 mL of distilled water. The control (T_1) had only 15 mL of distilled water. Moderate priming doses significantly improved several germination traits, including germination potential, germination energy, germination index, and average germination time. Among all treatments, T_4 (1.00 mL) consistently delivered the best results, exhibiting the highest germination potential (87.22%), maximum germination energy (86.32%), the quickest germination rate (T_{50} = 1.512 days), and the shortest mean germination time. Treatments T_3 (0.50 mL) and T_5 (2.00 mL) also enhanced germination compared to the control, whereas higher concentrations (T_6 and T_7) suppressed germination, indicating that excessive priming disrupts normal metabolic processes. Measurements of seedling growth emphasised the benefits of optimal priming levels. T_4 (1.00 mL) produced the tallest seedlings (31.20 cm) and the greatest fresh biomass, while T_3 (0.50 mL) generated the highest dry matter and achieved the greatest Vigour Index II, demonstrating improved seedling strength. The Vigour Index I was also highest in T_4 (2721.16), indicating strong early growth potential. In contrast, high priming concentrations (T_6 and T_7) reduced seedling height, biomass, and vigour indices, indicating that over-priming causes physiological stress that impedes early development. In summary, moderate seed priming, especially at 0.50 mL and 1.00 mL, significantly improves germination performance, seedling vigour, and biomass formation,

whereas excessive priming has a negative impact on both germination and growth. Appropriate T_4 priming levels (1.00 mL) promote unifor metabolic activation, balanced root-shoot development, and improved early seedling establishment in green gram.

Keywords: *Nutri-priming, green gram, germination, vigour*

INTRODUCTION

Green gram (*Vigna radiata* L.) is an important food legume cultivated mainly in South and Green gram, widely cultivated across South and Southeast Asia and a member of the Fabaceae family, is believed to have originated and been domesticated in India thousands of years ago before spreading to China and other parts of Southeast Asia [17]. The crop is well adapted to difficult conditions, withstanding low rainfall, high temperatures, and nutrient-deficient soils, making it ideal for low-input agricultural systems. Green gram is a nutritious legume with approximately 24% high-quality protein, 63% carbohydrates, and significant amounts of iron (0.03 to 0.06 mg g^{-1}) and zinc (0.02-0.04 mg g^{-1}) (Nair *et al*., 2013). Despite these advantages, its global productivity is low—around 0.5 t ha^{-1} ^{f}ar from the potential yield of 2.5-3.0 t ha^{-1} [18]. India leads global production, cultivating nearly 65% of the world's mung bean area (3.0 million ha) and accounting for roughly 54% (1.5 million tonnes) of total output [1].

Although green gram is commercially important, it often has poor and uneven germination, particularly under rainfed conditions and environmental stresses like drought, salinity, and temperature extremes [3]. Such stresses cause crop establishment to be delayed, weaken seedling vigour, and, ultimately, reduce yield potential.

Uniform and rapid seedling emergence is critical for achieving maximum yield because early vigour improves competitiveness, resource capture efficiency, and crop stand uniformity. Poor or delayed emergence, combined with low-vigour seedlings, results in uneven canopy development, increased weed infestation[13], and reduced productivity.

Seed priming has emerged as a cost-effective and efficient pre-sowing technique for improving green gram germination and early growth. This method involves controlled hydration of seeds to initiate metabolic processes while preventing radicle emergence, followed by drying to safe moisture levels. It is an effective pre-sowing strategy that improves uniformity, vigour, and early establishment by controlling pre-germination physiological activity [26,27]. Primed seeds generally achieve faster emergence, better stress tolerance, improved nutrient mobilization, and greater synchrony in germination.

It is an effective pre-sowing strategy that improves uniformity, vigour, and early establishment by controlling pre-germination physiological activity [26,27]. These methods improve field establishment and contribute to higher yields, especially under suboptimal growing conditions.

In this context, nutrient-based priming (nutri-priming) provides an additional benefit by providing essential macro and micronutrients during seed hydration, stimulating cellular metabolism, activating key enzymes, and improving antioxidant

responses. These physiological enhancements contribute to higher germination energy, reduced mean germination time (MGT), improved root–shoot development, and elevated vigour indices—traits crucial for robust early growth [19]. Early nutrient deficiencies can delay T_{50}, root formation, and seedling performance [6].

Understanding how nutri-priming affects specific germination and seedling parameters helps to clarify the underlying mechanisms and aids in developing effective, scalable priming treatments. Modifications in MGT and T_{50} indicate shifts in germination speed and coordination; increases in vigour indices reflect enhanced early growth; and changes in root-shoot allocation highlight adjustments in developmental priorities due to priming.

Therefore, the present study aims to assess the effects of nutri-priming on germination behavior and early seedling vigour in green gram using standardised physiological and germination metrics and to identify nutrient-priming concentrations that effectively improve germination, seedling vigour, and early establishment by comparing responses across treatments, providing valuable insights for improving crop productivity on a large scale.

MATERIALS AND METHODS

Seeds of green gram (variety Samrat) were obtained from the Department of Agronomy, BCKV. Prior to priming, the seeds were surface-sterilized using a 0.2% mercuric chloride solution for 2–3 minutes and then thoroughly rinsed with deionized water. Nutri-priming extracts were prepared from digested banana stems, and various concentrations were formulated as follows: 0.00 mL (T_1), 0.25 mL (T_2), 0.50 mL (T_3), 1.00 mL (T_4), 2.00 mL (T_5), 3.00 mL (T_6), and 4.00 mL (T_7), each diluted in 15 mL of distilled water. The control treatment (T_1) consisted solely of 15 mL of distilled water. Nutrient content in liquid formulation of banana stem were nitrogen (230mg/L), phosphorus (74.4mg/L), potassium (397.5mg/L), zinc (2.09mg/L), iron (5.9mg/L), manganese (8.07mg/L), copper (0.97mg/L). It was the tested report from soil testing laboratory, BCKV. For priming, seeds were soaked in the respective solutions for eight hours.

After priming, the seeds were shade-dried back to their original moisture level and subsequently placed in petri dishes and roll towel setups for the evaluation of germination traits and seedling vigour. All experimental treatments were arranged in a Completely Randomized Design (CRD) with four replications and conducted in the Seed Science and Technology Laboratory, Bidhan Chandra Krishi Viswavidyalaya.

Enumeration of Germination Metrices

Germination parameters, including germination potential (GP), time to 50% germination (T_{50}), germination energy (GE), germination index (GI), and mean germination time (MGT), were calculated using standard equations (Table 1).

Table 1: *Equations used to determine selected germination matrices.*

No.	Parameters	Equation	Reference
1	Germination potential (%)	*GP* = Number of normal germinated seeds/ Total number of seeds) x 100	ISTA, 1996[14]
2	Time to 50% germination (T_{50})	$T_{50} = ti + [\{(N / 2 – ni) \times (tj – ti)\} / (nj – ni)]$ Where ‘N’= the final number of seeds that germinated, and ‘ni’, ‘nj’ are the total number of seeds germinated by adjacent counts at	Coolbear *et al*., 1984; Farooq *et al*., 2005[9,12]

		times 'ti' and 'tj' when ni< N/2 <nj.	
3	Germination Energy (GE)	Percent of seeds germinated on 4th day after the initiation of the experiment, in relation to the total number of seeds tested	Ruan *et al*., 2002[25]
4	Germination Index (GI)	$GI = \Sigma$ (ni / di), for i = 1 to k	AOSA, 1983[2]
5	Mean Germination time (MGT)	$MGT = \Sigma$ (ni × di) / Σni, for i = 1 to k	Ellis and Roberts, 1981[11]
Where 'ni' is the number of seeds that emerged on day "di" and "d" is the number of days counted from the start of the test, k is the day of final count (14 days).			

Seedling Parameters

Root and shoot lengths were recorded on the 14th day after sowing by measuring ten randomly selected seedlings with a ruler and graph paper. The mean values were then used to determine the root-to-shoot ratio, and total seedling length (cm) was calculated by adding the root and shoot measurements.

Seedling fresh and dry weights were taken using a digital balance. For dry weight estimation, seedlings were oven-dried at 110 ± 2^0C for 24 hours. Both fresh and dry weights were expressed on a per-seedling basis (mg seedling^{-1}).

Seedling vigour indices were calculated following the method of Abdul-Baki and Anderson (1973):

SVI-I = Germination (%) × Mean seedling length (cm)

SVI-II = Germination (%) × Mean seedling dry weight (mg)

RESULTS AND DISCUSSION

Seed priming had a significant impact on the germination characteristics of green gram (cv. Samrat), with all germination parameters significantly different between treatments (Table 2). The observed responses clearly show a dose-dependent effect of priming.

Table 2: *Effect of Seed Priming on Germination Parameters of green gram (Vigna radiata L., cv. Samrat)*

Treatments	Germination potential (%) (Tr value)	Time to 50 per cent germination (days)	Germination energy (%) (Tr value)	Germination index	Mean germination time (days)
T_1 (Control)	82.82 (65.52) c	1.685 b	79.90 (63.36) d	36.82 d	2.475 c
T_2 (0.25 mL)	83.45 (66.00) c	1.613 d	81.07 (64.21) c	36.02 e	2.535 b
T_3 (0.50 mL)	85.95 (67.99) b	1.645 c	82.70 (65.42) b	39.05 c	2.365 d

T_4 (1.00 mL)	87.22 (69.06) a	1.512 e	86.32 (68.30) a	40.35 a	2.280 e
T_5 (2.00 mL)	86.60 (68.53) ab	1.608 d	81.12 (64.25) c	39.65 b	2.380 d
T_6 (3.00 mL)	81.42 (64.48) d	1.695 b	80.67 (63.92) c	35.37 f	2.365 d
T_7 (4.00 mL)	79.45 (63.04) e	1.745 a	79.35 (62.97) d	36.75 d	2.625 a
SEd (±)	**0.271**	**0.009**	**0.156**	**0.116**	**0.008**
CV (%)	**0.578**	**0.777**	**0.341**	**0.434**	**0.483**

Means followed by the same letter do not differ significantly (Tukey's HSD, α = 0.05).

Germination Potential (%)

The germination potential increased gradually with priming up to 1.00 mL concentration. The highest germination potential was observed in T_4 (1.00 mL) at 87.22% (Tr value 69.06), which was significantly greater than all treatments except T_5. Treatments T_3 (0.50 mL) and T_5 (2.00 mL) also increased germination potential compared to the control (T_1). Higher concentrations (T_6 and T_7), on the other hand, reduced germination potential, implying that over-priming may interfere with early germination processes. Ray *et al*. (2023)[23] found a comparable result in tomatoes. Chakraborty and Bordolui (2021) found that priming green gram with GA and Ag-Nanoparticles increased germination rate.[4]

Time to 50% Germination (T_{50}) (days)

Nutri-priming reduced T_{50}, suggesting faster germination. T_4 had the shortest T_{50} (1.512 days), indicating faster and more uniform seedling emergence. Treatments T_2, T_3, and T_5 also exhibited lower T_{50} values than the control (1.685 days). Conversely, the slowest germination occurred in T_7 (1.745 days), highlighting the negative effects of excessive priming. Choudhury *et al*. (2023)[8] found that PEG 6000 priming reduced chickpea germination time by 50%.

Germination Energy (%)

Germination energy followed a pattern similar to germination potential, with moderate priming levels providing substantial improvements. T_4 achieved the highest germination energy (86.32%), significantly surpassing all other treatments. T_3 and T_5 also increased energy values compared to the control, indicating enhanced metabolic activity. Lower energy levels in T_6 and T_7 reflected stress associated with over-priming. Choudhury *et al*. (2023) found comparable results in chickpea.[8]

Germination Index

The germination index, which captures both speed and uniformity, was greatest in T_4 (40.35), followed by T_5 (39.65) and T_3 (39.05), all of which were significantly

superior to the control. In contrast, T_6 recorded the lowest index (35.37), suggesting that higher priming doses impaired germination dynamics. Dandapat and Bordolui (2025) found similar results with rice.[10]

Mean Germination Time (MGT) (days)

Appropriate seed priming reduced MGT, with T_4 (2.280 days) showing the fastest completion of germination, followed by T_3 and T_5. Higher MGT values were observed in T_2 and T_7, with T_7 demonstrating the slowest germination (2.625 days), further confirming the inhibitory effect of over-priming. For rice, Dandapat and Bordolui (2025) reported similar findings.[10]

Table 3: *Effect of Seed Priming on Seedling Growth Parameters, Fresh Weight, Dry Weight, and Vigour Index (I and II) of green gram (Vigna radiata L., cv. Samrat).*

Treatments	Root Shoot length ratio	Seedling length (cm)	Seedling fresh weight (mg seedling^{-1})	Seedling dry weight (g seedling^{-1})	Vigour Index I	Vigour Index II
T_1 (Control)	0.730 b	23.09 f	225.00c	19.92c	1912.85 d	1650.16c
T_2 (0.25 mL)	0.512 d	26.38 c	244.25b	24.40 a	2201.89 c	2036.47b
T_3 (0.50 mL)	0.580 c	25.99 d	246.02 b	25.22 a	2233.91 c	2167.59a
T_4 (1.00 mL)	0.520 d	31.20 a	289.05 a	22.22b	2721.16 a	1938.39b
T_5 (2.00 mL)	1.438 a	27.00 b	226.11c	20.07c	2338.40 b	1738.01c
T_6 (3.00 mL)	0.502 d	22.75 f	170.07d	20.99bc	1852.82 e	1709.24c
T_7 (4.00 mL)	0.500 d	23.93 e	224.03c	16.25d	1901.15 d	1291.02d
SEd (±)	**0.012**	**0.19**	**2.66**	**0.46**	**19.68**	**36.93**
CV (%)	**2.442**	**1.02**	**1.62**	**3.03**	**1.28**	**2.92**

Means followed by the same letter do not differ significantly (Tukey's HSD, □= 0.05).

Seedling Growth, Biomass, and Vigour

Seed priming markedly affected seedling growth, biomass accumulation, and vigour indices in green gram (cv. Samrat), as shown in Table 3. The responses exhibited a clear dose-dependent trend, with moderate priming levels producing the most favourable outcomes.

Root–Shoot Length Ratio

The root-to-shoot ratio varied significantly among treatments. The highest ratio was recorded in T_5 (2.00 mL) at 1.438, indicating enhanced root development relative to shoot growth, which may improve nutrient and water uptake. Other treatments (T_2, T_3, T_4, T_6, and T_7) displayed lower ratios (0.50–0.58), reflecting a shoot-dominant growth pattern. The control (0.730) was intermediate, while excessive priming (T_6 and T_7) resulted in the lowest ratios.

Seedling Length (cm)

Optimal priming significantly increased seedling length. T_4 (1.00 mL) produced the longest seedlings (31.20 cm), demonstrating strong early vigour. T_2

(26.38 cm), T_3 (25.99 cm), and T_5 (27.00 cm) also exceeded the control in growth. However, the highest priming levels (T_6 and T_7) led to shorter seedlings, comparable to or below the control, suggesting inhibitory effects of over-priming due to physiological or osmotic stress. Choudhury and Bordolui (2022b) discovered similar results in bengal gram with Potassium Nitrate priming to lengthen shoots.[7]

Seedling Fresh Weight (mg)

Moderate priming resulted in increased fresh weight, with T_4 having the highest value (289.05 mg seedling^{-1}), followed by T_2 and T_3, all exceeding the control (225.00 mg). This increase likely reflected enhanced water uptake and early metabolic activation. In contrast, T_6 (170.07 mg) had the lowest fresh weight, demonstrating the negative impact of excessive priming on biomass growth. Kundu and Bordolui (2025) discovered a similar outcome in carrots following osmo-priming.[16]

Seedling Dry Weight (mg)

The highest dry weight was observed in T_3 (25.22 mg seedling^{-1}) and T_2 (24.40 mg), significantly exceeding both the control and higher priming levels. These findings indicate that moderate priming enhances structural biomass. Although T_4 showed the highest fresh weight, its lower dry weight (22.22 mg) suggests increased moisture retention rather than true biomass gain. Excessive priming (T_6 and T_7) resulted in the lowest dry weights, reflecting reduced metabolic activity and nutrient mobilization. Ray and Bordolui (2022a) found similar trends in tomato.[21]

Vigour Index I

Vigour Index I, which combines germination and seedling length, peaked in T_4 (2721.16), demonstrating superior early growth and seedling strength. T_5 (2338.40) and T_3 (2233.91) also showed elevated values compared to the control (1912.85). The lowest values were recorded in T_6 (1852.82) and T_7, confirming that over-priming impairs early vigour. Chakraborty *et al*. (2020)[5] and Ray and Bordolui (2022b)[22] found similar outcomes. Over-priming disrupts metabolic processes of enzyme activity [24].

Vigour Index II

Based on dry weight, T_3 had the highest Vigour Index II (2167.59), followed by T_2 (2036.47), indicating that moderate priming (0.50 mL) increased biomass-related vigour. Despite its high germination and fresh weight, T_4 has a lower VI-II, which was associated with lower dry matter. The lowest VI-II was found in T_7 (1291.02), demonstrated the negative effects of over priming. In contrast to other treatments, Chakraborty and Bordolui (2021)[4] found that Ag nano priming increased the fresh weight of green gram seedlings. Kundu and Bordolui (2023)[15] found similar results when studying carrots. Over-priming disrupts metabolic processes of ROS accumulation [20].

The correlogram (Fig. 1) supported the findings by revealing strong positive correlations ($r > 0.75$) between germination potential, germination energy, overall germination, root-to-shoot ratio, shoot length, root length, and the Vigour Indices I and II. These correlations were clustered together, indicating a coordinated relationship between germination and seedling vigour. Time to 50% germination (T_{50}) and mean germination time (MGT) correlated negatively with germination, indicating an inverse relationship with vigour. The study demonstrated how different traits interact during nutri-priming and emphasised the importance of seed vigour and germination in maintaining physiological activity.

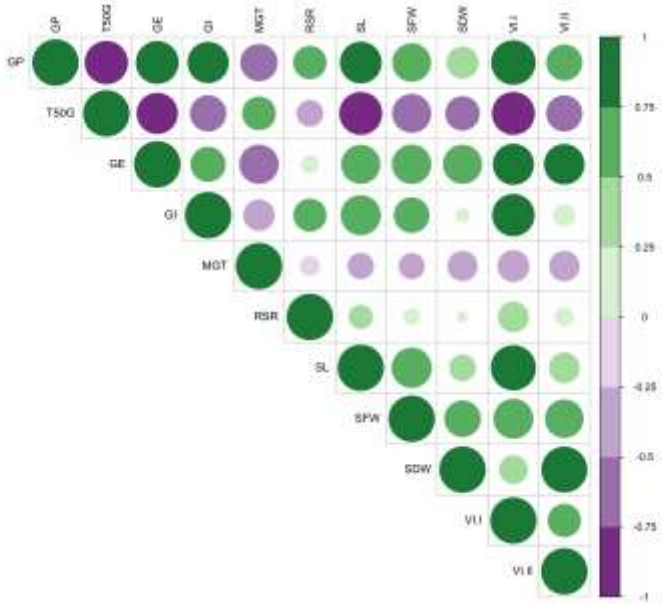


Fig. 1: *Pearson correlation matrix depicting pairwise correlation coefficients (r) for GP (Germination Potential), T_{50} (Time to 50% Germination), GE (Germination Energy), GI (Germination Index), MGT (Mean Germination Time), RSR (Root–Shoot length Ratio), SL (Seedling Length), SFW (Seedling Fresh Weight), SDW (Seedling Dry Weight), VI-I and VI-II (Vigour Index I and II). Blue cells indicate positive correlations, red cells indicate negative correlations, and colour intensity reflects the magnitude of r. Significance levels are denoted as $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***).*

CONCLUSION

The study found that seed priming had a significant, concentration-dependent effect on green gram germination and early seedling development (*Vigna radiata* L., cv. Samrat). Among the nutri-priming, T_4 (1.00 mL) consistently achieved the best results, with the highest germination potential, energy, speed, and uniformity. Moderate priming levels, such as T_3 (0.50 mL) and T5 (2.00 mL), also improved performance compared to the control, whereas higher concentrations (T_6 and T_7) reduced germination, most likely due to osmotic or chemical stress disrupting early metabolic processes. In terms of seedling growth and vigour, moderate priming, particularly T_3 and T_4, resulted in increased seedling length, biomass accumulation, and vigour indices. T_4 was the most effective in terms of seedling length, fresh weight, and Vigour Index I, while T_3 had the highest dry weight and Vigour Index II scores. Excessive priming (T_6 and T_7) reduced growth and vigour, highlighting the detrimental effects of over-priming on seedling metabolism. Overall, these findings suggest that optimal seed priming with T_4 (1.00 mL) improved physiological preparedness, metabolic activation, and balanced root-shoot development, resulting in increased early seedling vigour, whereas over-priming may impair germination and growth.

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