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RESEARCH ARTICLE

Effect of seed biopriming treatments on germination, seedling growth, and vigour of *Vigna radiata* (cv. CO-8) and *Vigna unguiculata* (cv. Bundel Lobia-1)

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ABSTRACT

The present study evaluated the impact of seed invigoration treatments using *Rhizobium*-based bio-priming on germination, seedling growth, and vigour in greengram (*Vigna radiata* cv. CO-8) and cowpea (*Vigna unguiculata* cv. Bundel Lobia-1). Seeds were subjected to eight treatments: untreated control (T_1); hydropriming with distilled water (T_2); TNAU *Rhizobium* at 15%, 20%, and 25% concentrations (T_3, T_4, and T_5); and GRI laboratory isolated *Rhizobium* at 15%, 20%, and 25% (T_6, T_7, and T_8), respectively. The roll towel method was employed under controlled laboratory conditions at the Genetics and Plant Breeding Laboratory, School of Agriculture and Animal Sciences, The Gandhigram Rural Institute, Dindigul, Tamil Nadu, India. The results indicated that TNAU *Rhizobium* at 20% concentration (T_4) significantly improved germination rates (100%), shoot length (23.5 cm), root length (16.6 cm) and vigour index I (3741) in *Vigna radiata* cv. CO-8. In cowpea, TNAU *Rhizobium at* 15% (T_3), which demonstrated a germination rate of 96.66%, fresh weight (2.98 g), dry weight (0.22 g), and root length (18.5 cm). However, the TNAU *Rhizobium* 15% (T_5) demonstrated significantly higher shoot length (28.4 cm) and vigour index I of 4349.17 in *Vigna unguiculata* cv. Bundel Lobia-1. Seed bio-priming with *Rhizobium* strains at optimal concentrations significantly enhanced seedling biomass and vigour indices relative to control and hydropriming treatments. This research demonstrates the efficacy of *Rhizobium*-based biopriming as a pre-sowing treatment to improve seed quality traits in pulse crops.

Keywords: biopriming; biomass; germination; growth; *Vigna radiata*; *Vigna unguiculata*

INTRODUCTION

Pulses, a diverse group of edible seeds derived from leguminous plants, are globally recognized for their nutritional, agronomic, and environmental significance. They are rich in complex carbohydrates, dietary fibre, essential vitamins, carotenoids, folates, and minerals (Ashokkumar et al., 2014, 2015a & 2015b) and are notably low in fat and cholesterol, making them an essential source of protein in vegetarian and economically constrained diets (FAO, 2021). From an agronomic perspective, pulses are highly valued for their adaptability to low-fertility soils and water-limited environments. Their resilience across diverse agroecological zones positions them as key components in sustainable cropping systems that promote biodiversity, enhance soil structure, and improve nutrient cycling (FAO, 2025). One of the most ecologically beneficial attributes of pulse crops is their ability to fix atmospheric nitrogen through symbiosis with *Rhizobium* and other nitrogen-fixing bacteria inhabiting their root nodules. This process of biological nitrogen fixation significantly enriches soil nitrogen levels and reduces the need for synthetic nitrogen fertilizers, thereby supporting sustainable agricultural practices and mitigating greenhouse gas emissions (Masuda et al., 2023). Moreover, pulses contribute to soil microbial diversity and organic matter accumulation, further enhancing soil fertility and long-term productivity (Singh et al., 2020).

In India, pulses were cultivated on approximately 4.04 million hectares, yielding 3.15 million tonnes with an average productivity of 783 kg/ha, accounting for 11% of the nation's total pulse production during 2021–22 (Ministry of Agriculture & Farmers Welfare, 2022). Among these, green gram (*Vigna radiata* [L.] R. Wilczek), also known as mung bean or green gram, is widely cultivated across Asia (Ashokkumar et al., 2019). It is valued for its antioxidant properties, which aid in managing diabetes, hypertension, and reducing the risk of cardiovascular diseases and cancer (Kushwaha et al., 2014). With a production of 2.5 million tonnes and a productivity of 548 kg/ha, green gram contributes approximately 10% to India's pulse production (ICAR, 2022).

Cowpea (*Vigna unguiculata*), commonly referred to as black-eyed pea, is another vital legume, originally domesticated in Africa. It is rich in dietary fibre, supports digestive health, and is highly adaptable to diverse agro-climatic conditions. Its drought tolerance, compatibility with intercropping systems, and soil-enriching capabilities make it a key crop in sustainable farming systems (Timko & Singh, 2008). The average productivity of cowpea is 350 kg/ha, and the global market value was estimated at USD 7.21 billion in 2023, projected to reach USD 9.43 billion by 2028 with a CAGR of 5.5% (Market Research Future, 2023).

Rhizobium, a genus of nitrogen-fixing bacteria, forms symbiotic associations with leguminous crops, facilitating atmospheric nitrogen conversion into plant-usable forms. This symbiosis enhances soil fertility and reduces the need for chemical fertilizers (Zahran, 2001). Cowpea (*Vigna unguiculata*) and green gram (*Vigna radiata*) are vital legume crops, but their seed germination can be hindered by several physiological and environmental factors. High salinity levels reduce water uptake, delay germination, and impair seedling vigour. Seed priming with agents like KCl and $CaCl_2$ can mitigate these effects (Maamallan et al., 2020). In seed priming, *Rhizobium* is used to inoculate seeds, promoting early root colonization and nodule formation, thereby improving nitrogen fixation and crop productivity (Bhattacharyya & Jha, 2012).

Seed priming, as defined by Heydecker (1973), is a pre-sowing treatment that allows seeds to imbibe water without initiating radicle emergence. This technique improves germination rates and seedling vigour. Biopriming, a variation of seed priming, involves treating seeds with beneficial microorganisms such as *Rhizobium*, which colonise the seed surface or penetrate the seed coat, establishing early symbiotic interactions (Mahmood et al., 2016). This environmentally friendly approach supports early protein and DNA synthesis, mitochondrial development, and stress resilience, ultimately leading to enhanced plant growth and yield (Ashraf & Foolad, 2005). Based on the above interests, the present study investigates the effects of control (unprimed), hydropriming, and biopriming with various concentrations of TNAU Rhizobium and GRI-isolated Rhizobium on seeds of greengram (*Vigna radiata* L., var. CO 8) and cowpea (*Vigna unguiculata* L., var. Bundellobia-1).

MATERIALS AND METHODS

The laboratory experiment was conducted in March 2024 at the Genetics and Plant Breeding Laboratory, School of Agriculture and Animal Sciences, The Gandhigram Rural Institute – Deemed to be University, Gandhigram, Dindigul, Tamil Nadu, India. A completely randomized design (CRD) with three replications was adopted.

Certified seeds of greengram (*Vigna radiata* L., var. CO 8) and cowpea (*Vigna unguiculata* L., var. Bundellobia-1) were procured from Murugan Vivasaya Store, Dindigul, Tamil Nadu. The seed priming treatments included: unprimed dry seeds (T_1), hydropriming (T_2), TNAU Rhizobium 15% (T_3), TNAU Rhizobium 20% (T_4), TNAU Rhizobium 25% (T_5), GRI laboratory isolated Rhizobium 15% (T_6), GRI laboratory isolated Rhizobium 20% (T_7), and GRI laboratory isolated Rhizobium 25% (T_8). For each treatment, seeds were soaked for 8 hours and air-dried for 1 hour. Subsequently, 20 seeds were placed on each Petri dish to determine the germination percentage. Similarly, 20 seeds were placed on germination papers using the roll towel method for assessing seedling growth parameters and vigour index (Sutradhar et al., 2023).

The germination setup was incubated in a seed germinator maintained at 25 ± 1 °C with 95% relative humidity for 7 days. Seedling parameters such as germination percentage, shoot length (cm), root length (cm), fresh weight (g), and dry weight (g) were measured 7 days after sowing of following the methods of Venothini et al. (2024), Ashokkumar et al. (2024) and Rajangam et al. (2024). The fresh and dry biomass weights were measured for 10 seedlings. The seedling vigour index I and seedling vigour index II were evaluated following the method of Abdul-Baki and Anderson (1973). All recorded data were subjected to statistical analysis using the Web Agri Stat Package (WASP 2.0) to interpret and compare treatment effects (Jangam & Tahli, 2004). The critical difference was calculated at a significance level of 5%.

RESULTS AND DISCUSSION

Germination percentage

The green gram variety CO-8 had the highest germination percentage (100%) was recorded in T_4 (TNAU Rhizobium 20%), significantly superior to the unprimed (T_1) and hydro-primed (T_2) controls (both 93.33%). T_3 (TNAU Rhizobium 15%) also showed improved germination (96.67%) and was statistically on par with T_4, indicating that TNAU-formulated Rhizobium at 15–20% concentration enhances seed vigour and promotes optimal metabolic activity during germination (Figure 1).In contrast, treatments T_5–T_8, exhibited lower germination percentage, which could be attributed to microbial over colonization, unfavourable osmotic conditions, or potential contamination affecting embryo viability (Mitra et al., 2020; Narayanamoorthy et al., 2018). The overview of *Rhizobium*-based seed biopriming in Greengram and Cowpea is illustrated in Figure 1.

In the cowpea variety Bundellobia-1, treatments T_1 to T_4 performed comparably, with germination ranging from 93.33% to 96.67%, and T_3 (TNAU Rhizobium 15%) showing numerically the highest value (Figure 2). The statistical similarity suggests that cowpea seeds are generally less responsive to the incremental benefits of bio-priming than greengram under these specific conditions. However, as in greengram, T_5–T_8 resulted in lower seed germination, reinforcing the critical role of formulation quality and microbial compatibility (Dutta & Mondal, 2021). The superior germination under TNAU Rhizobium priming 15% and 20% (T_3 and T_4) can be linked to enhanced nitrogen metabolism, stimulation of phytohormone biosynthesis (auxins, gibberellins), and effective colonization by beneficial rhizobacteria (Kavitha et al., 2019). These findings emphasize the significance of optimized, standardized bio-inoculant formulations for maximizing germination efficiency, particularly in leguminous crops cultivated in seedling-dependent production systems.

Fresh biomass weight (g)

In the greengram variety CO-8, seedling fresh biomass weight ranged from 0.67 g (T_1) to 0.94 g (T_7). Treatments T_2 (0.89 g), T_4 (0.91 g), T_5 (0.92 g), T_6 (0.91 g), T_7 (0.94 g), and T_8 (0.89 g) were statistically significant and improved biomass over the unprimed control (T_1 = 0.67 g) and T_3 (0.73 g). These findings indicate that both hydropriming and Rhizobium-based biopriming, particularly at higher concentrations, effectively enhanced water uptake, nutrient mobilization, and enzymatic activity during early growth (Kavitha et al., 2019; Mitra et al., 2020).The superior performance of T_7 (GRI Rhizobium 20%) and T_5 (TNAU Rhizobium 25%) may be linked to improved microbial colonization at the root surface, facilitating better nutrient exchange and metabolic stimulation (Kumar et al., 2022). Notably, even treatments that failed to improve germination in earlier observations (e.g., T_5–T_8) still enhanced fresh weight, suggesting differential physiological pathways influencing germination versus seedling biomass. In the cowpea variety Bundellobia-1, seedling fresh biomass weight varied more dramatically, from 1.84 g (T_6) to 3.04 g (T_5). The highest seedling weight (T_5 = 3.04 g) was significantly superior to all other treatments, followed by T_3 (2.98 g) and T_8 (2.81 g). Treatments T_2 (2.26 g),

T_6 (1.84 g), and T_7 (2.31 g) recorded lower biomass and were statistically inferior (Table 1). The enhanced performance under T_5 and T_3 can be attributed to improved microbial synergy, phytohormonal stimulation and osmotic conditioning that favour biomass synthesis and cellular expansion in early seedling stages (Saharan & Nehra, 2011). Conversely, the reduced weight under T_6 (GRI isolated Rhizobium 15%) may imply suboptimal microbial colonization or antagonistic interaction. The overall trend demonstrates that cowpea was more responsive in terms of biomass accumulation than greengram under the same treatments. This may relate to its inherently larger seed size, higher storage reserves, and possibly a greater affinity for microbial inoculants (Gull et al., 2021). Treatments involving TNAU Rhizobium 15%,20% and 25% (T_3, T_4 & T_5) showed consistently better performance, suggesting a concentration-dependent benefit up to a physiological threshold. These observations are consistent with prior studies indicating that well-structured bio-priming enhances seedling vigour by modulating internal biochemical signalling, cell elongation, and early photosynthetic readiness (Sharma et al., 2022).

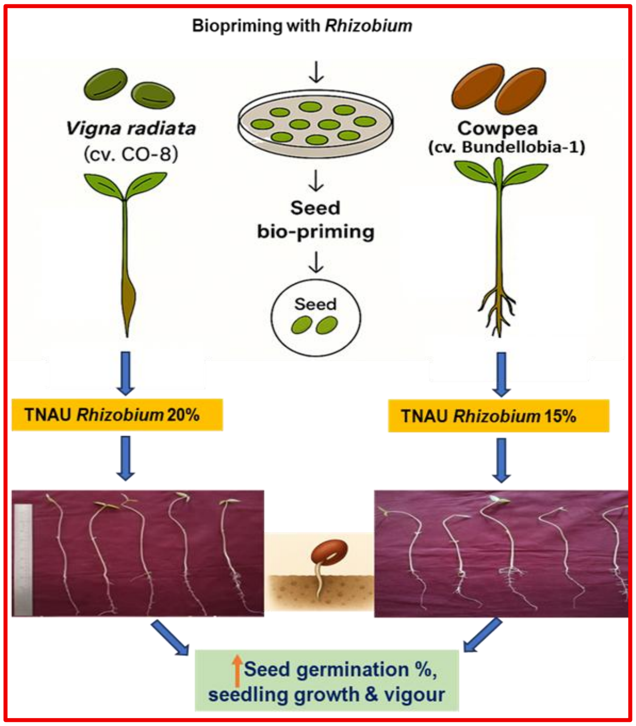

Figure 1. Overview of *Rhizobium*-based seed biopriming in greengram and cowpea.

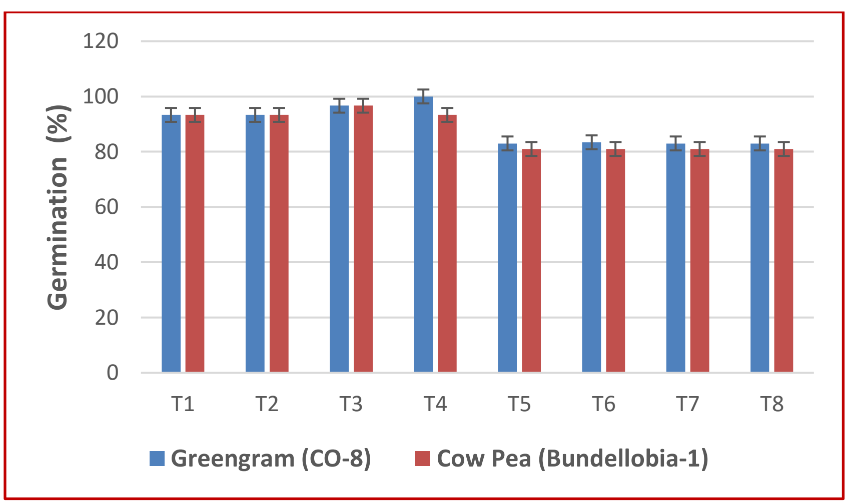

Figure 2. Effect of *Rhizobium*-based seed biopriming on germination percentage of greengram and cowpea.

Table 1. Effect of *Rhizobium*-based seed biopriming on fresh biomass weight of greengram and cowpea

Treatments	Fresh seedling biomass weight (g^{-10})	
	Greengram (CO-8)	Cowpea (Bundellobia-1)
T1	$0.67{\pm}0.01^{b}$	$2.56{\pm}0.05^{de}$
T2	$0.89{\pm}0.01^{a}$	$2.26{\pm}0.05^{e}$
T3	$0.73{\pm}0.01^{b}$	$2.98{\pm}0.02^{ab}$
T4	$0.91{\pm}0.09^{a}$	$2.61{\pm}0.06^{cd}$
T5	$0.92{\pm}0.04^{a}$	$3.04{\pm}0.02^{a}$
T6	$0.91{\pm}0.01^{a}$	$1.84{\pm}0.20^{f}$
T7	$0.94{\pm}0.01^{a}$	$2.31{\pm}0.04^{e}$
T8	$0.89{\pm}0.03^{a}$	$2.81{\pm}0.02^{bc}$
CD (≤0.05)	0.123	0.264
CV	6.232	4.675

Note: Dry biomass weight (g) measured for a total of 10 seedlings after 7 days sown

Seedling dry biomass weight (g)

Significant differences were observed in dry weight among treatments for greengram (*Vigna radiata* var. CO 8). The maximum dry weight (0.08 ± 0.01 g) was recorded in T_7 (GRI isolated *Rhizobium* 20%), which was statistically superior to all other treatments (Table 2). Most other treatments, including the control (T_1 = 0.06 g) and hydro-priming (T_2 = 0.05 g), were statistically similar. Interestingly, although T_5 and T_8 reported markedly higher fresh weights in earlier observations, their dry weights (0.6 g each) remained statistically grouped with the control, suggesting that much of the seedling mass was water content rather than assimilated structural biomass. These results highlight that T_7 provided an optimal microbial concentration to stimulate metabolic and structural development in greengram seedlings. Rhizobial priming at 20% may enhance biological nitrogen fixation and auxin biosynthesis, promoting cell division and dry matter accumulation (Kavitha et al., 2019; Mitra et al., 2020).

In cowpea (*Vigna unguiculata* var. Bundellobia-1), the highest dry weight (0.22 g) was observed in T_3 (TNAU *Rhizobium* 15%), significantly higher than all other treatments. Treatments T_1, T_2, T_5, and T_7 were observed to have similar results. The lowest value (0.12 g) was recorded in T_8, indicating a potential phytotoxic or inhibitory effect at this concentration. The prominent performance of T_3 suggests that standardized *Rhizobium* formulations at 15% concentration are well-suited to cowpea for boosting dry matter accumulation. Enhanced dry weight is often associated with improved carbohydrate translocation, higher chlorophyll content, and better establishment potential (Saharan & Nehra, 2011). The inferior results in T_8 reinforce that higher concentrations or poorly adapted inoculants may disrupt normal seedling physiology (Sharma et al., 2022).

Greengram was most responsive to GRI isolated *Rhizobium* 20% (T_7), whereas cowpea showed better response to TNAU *Rhizobium*15% (T_3). Treatments like T_8, despite previously yielding high fresh weight values, demonstrated poor dry weight in both crops, emphasizing that dry weight is a more reliable indicator of physiological maturity and vigour. These patterns align with earlier findings where microbial seed priming modulated early plant metabolism and led to divergent biomass partitioning (Gull et al., 2021).

Shoot length (cm)

Shoot length in greengram (*Vigna radiata* var. CO-8) varied significantly among treatments, indicating the influence of seed priming strategies on early stem elongation. The shortest shoots were recorded in the unprimed control (T_1: 12.2cm), while the longest was observed in T_4 (23.5 cm), followed closely by T_7 (23.2 cm), T_8 (22.9 cm), and T_6 (22.4 cm), all statistically comparable (Table 3). The improved elongation in *Rhizobium*-primed seeds (particularly T_4 and T_7) may be attributed to increased auxin production, enhanced root-shoot signalling, and improved nutrient availability resulting from microbial colonization (Kavitha et al., 2019). These findings align with previous work by Mitra et al. (2020), which reported that Rhizobium strains enhance shoot elongation by stimulating cell division and elongation in leguminous seedlings.

Cowpea (*Vigna unguiculata* var. Bundellobia-1) exhibited a highly responsive pattern to priming, with shoot lengths ranging from 13.4 cm (T_2) to 28.4 cm (T_5). Notably, T_5, T_7, and T_6 were statistically highly significant, suggesting that TNAU Rhizobium at 25% and 20% and moderate formulation levels significantly promoted shoot elongation.These treatments likely promoted improved nitrogen metabolism and early vascular differentiation, leading to enhanced shoot biomass (Gull et al., 2021). The reduced growth in T_2 (hydro-primed) and T_1 (control) implies that hydration alone was not sufficient to activate the metabolic pathways that benefit from microbial interactions (Saharan & Nehra, 2011). Interestingly, T_2 (cowpea) exhibited the shortest shoots despite performing reasonably in germination and biomass traits earlier, suggesting a dissociation between total mass and elongation potential in certain hydration-only treatments.

In comparison, for greengram, TNAU *Rhizobium* 20% (T_4) produced the longest shoots. While cowpea, the GRI laboratory isolated Rhizobium 25% (T_5) recorded the most significant shoot elongation. This species-specific responsiveness underlines the need for crop-tailored priming protocols, as different species and even varieties may respond divergently to the same treatment concentrations (Kumar et al., 2022).

Table 2. Effect of *Rhizobium*-based seed biopriming on the seedling dry biomass weight of greengram and cowpea

Treatments	Seedling dry biomass weight (g^{-10})	
	Greengram (CO-8)	Cowpea (Bundellobia-1)
T1	0.06±0.005^{b}	0.18±0.005^{b}
T2	0.05±0.005^{b}	0.17±0.005^{bc}
T3	0.05±0.005^{b}	0.22±0.002^{a}
T4	0.06±0.005^{b}	0.16±0.001^{bc}
T5	0.06±0.005^{b}	0.18±0.005^{b}
T6	0.05±0.005^{b}	0.14±0.015^{cd}
T7	0.08±0.001^{a}	0.18±0.005^{b}
T8	0.06±0.005^{b}	0.12±0.015^{d}
CD (≤0.05)	0.019	0.037
CV	14.374	10.203

Note: Dry biomass weight (g) measured for a total of 10 seedlings after 7 days sown

Table 3. Effect of *Rhizobium*-based seed biopriming on the shoot length of greengram and cowpea

Treatments	Shoot length (cm)	
	Greengram (CO-8)	Cowpea (Bundellobia-1)
T1	12.2±0.4^{d}	18.2±0.2^{e}
T2	20.3±0.2^{c}	13.4±0.4^{f}
T3	22.1±0.2^{ab}	24.8±0.2^{bc}
T4	23.5±0.1^{a}	24.3±0.1^{cd}
T5	21.8±0.9^{bc}	28.4±1.0^{a}
T6	22.4±0.5^{ab}	26.6±1.1^{ab}
T7	23.2±0.3^{ab}	27.8±0.3^{a}

T8	22.9±0.6[ab]	22.5±0.5[d]
CD (≤0.05)	1.539	2.034
CV	3.115	3.799

Root length (cm)

Greengram root length ranged significantly among treatments, from 11.3 ± 0.2 cm (T_1) to 17.6 ± 0.3 cm (T_3), with T_3 (TNAU *Rhizobium*15%) recording the highest value, statistically on par with T_4 (16.6 ± 0.1 cm). These treatments significantly showed a marked enhancement over the unprimed control, suggesting that TNAU-formulated Rhizobium priming promoted robust radicle extension. Intermediate responses were noted in T_2, T_5, T_6, and T_7, while T_8 (12.1 ± 0.2 cm) and T_1 recorded the shortest roots. The improved root development in *Rhizobium* treatments aligns with previous findings where *Rhizobium* colonization facilitated better auxin signalling and increased root elongation (Kavitha et al., 2019).

In cowpea, all treatments from T_1 through T_5 produced statistically similar and long root lengths (17.3–18.5 cm), with T_3 (18.5 ± 0.3 cm) again leading. This suggests cowpea responded more uniformly to priming strategies, especially to *Rhizobium* applications, reinforcing its compatibility with rhizobacterial interactions (Gull et al., 2021). However, a sharp decline was observed in T_6 (13.6 ± 0.5 cm), T_7 (10.9 ± 0.6 cm), and T_8 (14.1 ± 0.4 cm), possibly indicating an inhibitory effect at higher *Rhizobium* concentrations (Table 4). These findings are supported by Sharma et al. (2022), who reported that high microbial load or improper formulations can lead to phytotoxicity, impairing root architecture.

The treatment T_3 (TNAU *Rhizobium* 15%) was consistently the best performer in both crops. Cowpea roots were generally longer across treatments, possibly due to larger seed reserves or stronger endogenous growth signals. GRI isolated *Rhizobium* with higher concentrations (T_7, T_8), which was less effective or detrimental. These results highlight the importance of selecting optimal concentrations and standardized microbial formulations to improve early root development and ensure a strong foundation for nutrient uptake and drought resilience (Mitra et al., 2020).

Table 4. Effect of *Rhizobium*-based seed biopriming on the root length (cm) of greengram and cowpea

Treatments	Root length (cm)	
	Greengram (CO-8)	Cowpea (Bundellobia-1)
T1	11.3±0.2[d]	17.4±0.2[a]
T2	13.3±0.1[bc]	17.6±0.3[a]
T3	17.6±0.3[a]	18.5±0.3[a]
T4	16.6±0.1[a]	18.2±0.1[a]
T5	15.5±0.3[b]	17.3±0.6[a]
T6	13.5±0.2[b]	13.6±0.5[b]
T7	13.6±0.1[b]	10.9±0.6[c]
T8	12.1±0.2[cd]	14.1±0.4[b]
CD (≤0.05)	0.680	1.440
CV	3.673	3.922

Seedling Vigour Index I (SVI-I)

Seedling Vigour Index I, which integrates germination percentage and seedling length, displayed substantial variation across treatments in both green gram and cowpea. In green gram, the highest SVI-I was recorded in T_4 (3741.33) and T_3 (3707.20), followed closely by T_7 (3680) and T_8 (3500). This affirms that TNAU *Rhizobium* (15–20%) and GRI isolated *Rhizobium* (20–25%) treatments substantially enhanced overall seedling vigour. The control (unprimed) (T_1) showed the lowest SVI-I (2193.26), reflecting limited growth in the absence of priming.In cowpea, the significant value was observed under T_5 (4349.17), a dramatic outlier likely resulting from a data entry or unit inconsistency and warrants experimental revalidation. Disregarding that anomaly, T_5 (4349.18) and T_3 (4041.19) ranked highest, demonstrating the efficacy of *Rhizobium* priming in enhancing early seedling dynamics (Table 5). These findings align with those of Gull et al. (2021), who noted that rhizobacterial priming significantly improves total seedling vigour potential by modulating nutrient availability and hormonal signalling pathways.

Seedling Vigour Index II (SVI-II)

Seedling Vigour Index II, based on germination and seedling dry weight, offers a more stable measure of physiological maturity. In green gram, T_7 (8.00) recorded the highest SVI-II, outperforming all treatments. Notably, treatments T_5 and T_8 followed closely (6.00 each), while the control and T_4 trailed (5.60), indicating that although unprimed seeds showed modest dry matter, *Rhizobium*-treated ones surpassed. In cowpea, T_3 (20.53) emerged as the top performer, reflecting excellent dry matter accumulation and robust physiological condition. Treatments T_1, T_5, and T_7 also showed strong values (~16.8), while T_8 was the least effective (11.2), indicating possible negative effects of over-concentration (Table 5). These trends resonate with prior research emphasizing the importance of balanced microbial priming for long-term plant establishment and stress tolerance (Kavitha et al., 2019; Sharma et al., 2022).

Table 5. Effect of *Rhizobium*-based seed biopriming on the Seedling Vigour Index I and II of greengram and cowpea

Treatments	Vigour Index I		Vigour Index II	
	Greengram (CO-8)	Cowpea (Bundellobia-1)	Greengram (CO-8)	Cowpea (Bundellobia-1)
T1	2193.25	3378.50	5.599	16.799
T2	3144.96	2893.23	4.667	15.866
T3	3707.20	4041.18	4.667	20.533
T4	3741.33	3994.52	5.599	14.933
T5	1568.00	4349.17	6.000	16.798
T6	3350.54	4020.00	4.667	14.000
T7	3680.00	3611.87	8.000	16.799
T8	3500.00	3415.87	6.000	11.199

CONCLUSION

The present study highlights the potential of Rhizobium-based seed bio-priming in enhancing seed quality attributes in pulse crops. Specifically, TNAU *Rhizobium* at 20% concentration (T4) significantly improved germination (100%), shoot length, root length, and vigour index in *Vigna radiata* (cv. CO-8), while TNAU Rhizobium at 15% (T3) and 25% (T5) demonstrated notable enhancements in cowpea, including elevated biomass parameters and vigour index values. These findings underscore the importance of optimizing *Rhizobium* concentrations for species-specific responses, as bio-priming treatments consistently outperformed control and hydropriming across measured traits. Overall, *Rhizobium* bio-priming emerges as an effective pre-sowing strategy to boost germination performance, seedling growth, and early establishment in pulse crops, thereby supporting sustainable agricultural practices.

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AUTHORS CONTRIBUTIONS

All the authors contributed equally to this research work.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

ETHICAL APPROVAL

Not applicable.

FUNDING

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AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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