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Influence of liquid biofertilizer seed treatments on the seed quality parameters of soybean (*Glycine max* (L.) Merrill.)

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ABSTRACT

Seed quality is a critical component of soybean seed production because germination and seedling vigour determine the capacity of a seed lot to establish a uniform crop. The present study evaluated the effect of eleven liquid biofertilizer seed treatments on the quality of soybean cv. MAUS-612 seed harvested from a field experiment conducted during kharif, 2025–26 at the Seed Technology Research Unit, VNMKV, Parbhani, Maharashtra. The experiment was arranged in a randomized block design with three replications, and liquid inoculants were applied at 20 ml kg⁻¹ seed. Harvested seed was evaluated for germination, Vigour Index-I and Vigour Index-II. Treatment effects were highly significant for all three parameters. *Rhizobium* (T₂) was the best treatment, recording 95.86% germination, 2122.47 Vigour Index-I and 3569.50 Vigour Index-II. *Rhizobium* + PSB (T₉) ranked second for all three parameters, with 94.00% germination, 2094.73 Vigour Index-I and 3362.80 Vigour Index-II. PSB (T₃) ranked third, recording 93.66% germination, 1988.80 Vigour Index-I and 3033.73 Vigour Index-II. The untreated control recorded the lowest values for all three parameters. *Rhizobium* + PSB + KSB (T₁₀), although the strongest treatment for field seed yield in the companion experiment, produced 93.00% germination and intermediate vigour indices. The contrasting ranking demonstrates that agronomic yield and physiological quality are complementary selection criteria in seed-production research. The findings agree with earlier reports showing that *Rhizobium*, PSB and microbial consortia can improve harvested seed quality through improved plant nutrition, nodulation and seed development.

Keywords: Soybean seed, Germination, Seed vigour, Vigour Index-I, Vigour Index-II, *Rhizobium*, PSB, Liquid biofertilizer, Seed quality

Introduction

Seed quality is fundamental to the success of soybean production because high germination and vigorous seedlings are required for rapid and uniform establishment. In seed-production programmes, evaluation of harvested seed quality is therefore necessary in addition to measuring field yield. Germination percentage reflects the capacity of a seed lot to produce normal seedlings, while vigour indices provide a broader indication of seedling performance under test conditions.

Biofertilizers may affect harvested seed quality indirectly through improved nutrition, root development, nodulation, photosynthetic activity and assimilate supply during seed filling. *Rhizobium* is particularly important in soybean because biological nitrogen fixation supports nitrogen nutrition. PSB can improve phosphorus availability, and KSB can increase potassium availability. Other beneficial microorganisms can influence root growth, nutrient acquisition and plant physiological efficiency. Consequently, biofertilizer-treated plants may produce seed with improved germination and seedling vigour.

The literature reviewed in this paper provides substantial support. Lakshmi *et al.* (1997) [1] reported improved nodulation, root development and plant growth with *Rhizobium* treatment. Siddaraju *et al.* (2018) [2] observed improved germination, seedling length, dry matter and vigour in soybean seed harvested from inoculated plots. Joshi *et al.* (2018) [3] reported strong seed-quality responses to PSB treatment. Bazzo *et al.* (2020) [4] showed that microbial inoculation and co-inoculation could improve physiological seed quality. Ghadge *et al.* (2020) [5] recorded high germination and plant vigour with a *Rhizobium* + PSB + KMB consortium. Dalvi *et al.* (2021) [6] also found improved germination and vigour under bioagent-based seed coating.

However, a treatment that is highly productive in the field does not necessarily have to be the treatment that produces the most vigorous harvested seed. The present investigation therefore focused specifically on the physiological quality of seed produced under eleven liquid biofertilizer treatments and compared the response of germination and two vigour indices.

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Objective

To study the effect of liquid biofertilizers on seed quality of soybean.

Materials and methods

The field experiment was conducted during *kharif*, 2025–26 at the Seed Technology Research Unit, VNMKV, Parbhani, Maharashtra, using soybean cv. MAUS-612. The trial followed randomized block design with three replications and eleven treatments. Gross plot size was 2.7×4.0 m, net plot size was 1.8×4.0 m, spacing was 45×5 cm, seed rate was 65 kg ha^{-1} and fertilizer was applied at 30:60:30 kg N:P:K ha^{-1} . Sowing was performed on 3 July 2025.

The treatments were T_1 control; T_2 *Rhizobium*; T_3 *Rhizobium* + KSB; T_4 EM culture; T_5 PSB; T_6 KSB; T_7 *Azospirillum*; T_8 *Pseudomonas*; T_9 *Rhizobium* + PSB; T_{10} *Rhizobium* + PSB + KSB; and T_{11} VNMKV Biomix. Liquid inoculants were applied at 20 ml kg^{-1} seed.

After harvest, 100 seeds per replication were tested by the rolled towel paper method. Germination was evaluated under controlled conditions, with first count on day 5 and final count on day 8. Vigour Index-I was calculated as standard germination (%) $\times$ seedling length (cm), and Vigour Index-II as standard germination (%) $\times$ seedling dry weight (mg), following the methodology stated in the thesis and ISTA procedures.

Treatment differences were assessed using analysis of variance according to Panse *et al.* (1954) [7], with standard error and critical difference at 5% probability used for mean comparison.

Results and discussion

Treatment effects were highly significant ($P = 0.01$) for germination, Vigour Index-I and Vigour Index-II. Replication effects were non-significant, indicating reasonable experimental uniformity.

Table 1. Effect of liquid biofertilizer seed treatments on physiological quality of soybean seed.

Treatment	Biofertilizer	Germination (%)	Vigour Index-I	Vigour Index-II
T_1	Control	87.00	1696.20	2687.17
T_2	<i>Rhizobium</i>	95.86	2122.47	3569.50
T_3	<i>Rhizobium</i> + KSB	87.60	1745.20	2698.03
T_4	EM culture	90.40	1757.13	2699.67
T_5	PSB	93.66	1988.80	3033.73
T_6	KSB	91.33	1817.67	2811.33
T_7	<i>Azospirillum</i>	92.40	1847.63	2860.17
T_8	<i>Pseudomonas</i>	92.33	1822.73	2835.13
T_9	<i>Rhizobium</i> + PSB	94.00	2094.73	3362.80
T_{10}	<i>Rhizobium</i> + PSB + KSB	93.00	1877.93	2890.43
T_{11}	VNMKV Biomix	91.33	1782.73	2779.93
	GM	91.72	1868.48	2929.81
	$SE_{\pm}$	0.93	52.81	88.80
	CD 5%	2.74	155.79	261.97

Germination percentage

Germination ranged from 87.00 to 95.86%, with a mean of 91.72%. T_2 *Rhizobium* recorded the highest germination (95.86%), followed by T_9 *Rhizobium* + PSB (94.00%) and T_5 PSB (93.66%). These three treatments were therefore the best performers for germination. T_{10} recorded 93.00%, while the control was lowest at 87.00%. The 8.86 percentage-point advantage of T_2 over the control indicates a substantial improvement in the physiological quality of harvested seed.

The superiority of *Rhizobium* is consistent with its role in nodulation and biological nitrogen fixation. Better nitrogen nutrition during seed formation can support protein synthesis, seed development and the production of physiologically competent seed. The present observation agrees with Bazzo *et al.* (2020) [4], who found higher physiological quality following microbial inoculation, and Siddaraju *et al.* (2018) [2], who reported improved germination in inoculated soybean. Joshi *et al.* (2018) [3] reported particularly high germination with PSB treatment, which is also reflected in the strong ranking of T_5 in the present study. Dalvi *et al.* (2021) [6] and Dhutmal *et al.* (2025) [8] likewise reported improved germination under bioagent and liquid-biofertilizer treatments.

Vigour Index-I

Vigour Index-I ranged from 1696.20 to 2122.47, with a mean of 1868.48. T_2 was highest (2122.47), followed by T_9 (2094.73) and T_5 (1988.80). T_{10} recorded 1877.93 and the control had 1696.20. The same three treatments that ranked highest for germination also ranked first, second and third for

Vigour Index-I. This consistency strengthens the evidence that T_2 , T_9 and T_5 produced physiologically superior harvested seed rather than merely increasing the germination percentage.

Because Vigour Index-I incorporates seedling length, the high values under T_2 and T_9 indicate that the resulting seedlings were not only capable of germination but also developed greater length under the test conditions. Manjanagouda *et al.* (2025) [9] reported higher vigour indices after liquid-biofertilizer biopriming, while Shewale *et al.* (2024) [10] observed improved seedling vigour under a multifunctional bio-consortium. Ghadge *et al.* (2020) [5] also recorded strong seedling performance under *Rhizobium* + PSB + KMB inoculation.

Vigour Index-II

Vigour Index-II ranged from 2687.17 to 3569.50, with a mean of 2929.81. T_2 recorded the highest value (3569.50), followed by T_9 (3362.80) and T_5 (3033.73). The control recorded 2687.17. Thus, the same three treatments remained the top performers when seedling dry weight was incorporated into the vigour assessment. The advantage of T_2 over control was 882.33 index units, showing a strong difference in seedling biomass production.

Siddaraju *et al.* (2018) [2] specifically identified *Rhizobium* as an effective inoculant for improving soybean seed physiological quality. Dhutmal *et al.* (2025) [8] reported enhanced germination and vigour in *Rhizobium*- and KSB-treated plots, while Lakshmi *et al.* (1997) [1] linked *Rhizobium* treatment with improved nodulation and plant development. These reports provide a biological basis for the present superiority of *Rhizobium*-treated seed lots.

The three best treatments

Rhizobium (T_2) was the clear overall leader, ranking first for germination, Vigour Index-I and Vigour Index-II. *Rhizobium* + PSB (T_9) ranked second for every quality parameter, making it the most consistent combined treatment. PSB (T_5) ranked third for all three parameters and therefore also deserves attention where seed physiological quality is the primary criterion. The uniformity of this top-three ranking is stronger than the treatment ranking observed for field yield, where several treatments were trait-specific leaders.

The strong performance of T_2 may be associated with effective nodulation and biological nitrogen fixation during crop growth, while the response of T_9 suggests that combining nitrogen fixation with phosphorus solubilization can support seed development and seedling performance. T_5 also performed strongly, in agreement with the literature reviewed in the thesis. Nevertheless, the mechanism cannot be established directly from the present data because microbial population, nutrient uptake and seed biochemical composition were not measured.

Overall interpretation and seed-production relevance

Taken together, the three quality indicators demonstrate that liquid biofertilizer seed treatment can improve the physiological quality of harvested soybean seed relative to untreated control. The response was especially pronounced with *Rhizobium* and *Rhizobium* + PSB. This is consistent with the broader concept that beneficial microorganisms can improve plant nutrition and physiological efficiency during seed development. Therefore, assessment of seed quality is desirable when selecting biofertilizer treatments for seed-production systems.

Conclusion

Liquid biofertilizer seed treatments significantly influenced germination and seed vigour of soybean cv. MAUS-612. *Rhizobium* (T_2) was the best treatment for all three quality indicators, followed by *Rhizobium* + PSB (T_9) and PSB (T_5). The untreated control was consistently inferior. The results support the use of liquid microbial seed treatment as a promising approach for producing physiologically superior soybean seed, but treatment selection should consider both seed yield and seed quality. Further multi-season and multi-location studies should confirm the stability of these responses.

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