



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 1500-1505
Received: 19-05-2026
Accepted: 23-06-2026

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Effect of biofertilizers and nano-fertilizers for enhancing seed yield and its quality parameters in off season soybean (*Glycine max.* L.)

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7s.6153>

Abstract

A field study “Effect of different biofertilizers and nano-fertilizers treatments on seed yield and its quality parameters in off season soybean (*Glycine max* L.) cv. GS 4” was conducted at the Seed Testing Laboratory, Department of Seed Science and Technology, JAU, Junagadh for laboratory experiment and Sagdividi Farm, Department of Seed Science and Technology, JAU, Junagadh for field experiment during summer 2025 using randomized block design with factorial concept for field study and completely randomized design with factorial concept for laboratory study. The experiment comprised of six biofertilizers seed treatments (S₁: *Rhizobium*, S₂: PSB, S₃: KMB, S₄: ZSB, S₅: SOB and S₆: NPK consortia) and three nano-fertilizers foliar treatments (F₁: 4% Nano Urea, F₂: Nano DAP and F₃: Nano Zn) along with absolute control. Among the seed treatments, seed treated with PSB (S₂) and among the foliar treatments, foliar spraying with Nano DAP (F₂) recorded the maximum plant height at maturity (cm), number of clusters per plant, number of pods per plant, number of pods per cluster, number of seeds per pod, number of seeds per plant, biological yield per plant (g), seed yield per plant (g), test weight (g) and harvest index (%) along with seed quality parameters viz., germination (%), shoot length (cm), root length (cm), seedling length (cm), seedling dry weight (mg), seedling vigour index I and seedling vigour index II with the lowest days to 50 per cent flowering and days to maturity.

Keywords: Soybean (*Glycine max* L.), biofertilizers, nano-fertilizers, PSB, nano DAP

Introduction

Soybean [*Glycine max* (L.) Merrill], often hailed as the "Golden Bean" or "Miracle Crop", stands as the world's most economically significant leguminous species (Kumar *et al.*, 2013) [14]. Its unique position in global agriculture stems from its dual-purpose utility as both a high-protein pulse and a premier oilseed. In India, soybean cultivation has seen substantial growth since its introduction in 1977, with the country now ranking fifth globally in production, contributing 14.98 million tons in 2023 (Anon., 2025a). The crop's nutritional profile is peerless among edible legumes, containing approximately 40-42% protein and 20% edible oil (Gopalan *et al.*, 1989) [7]. Beyond quantity, the quality of soybean protein is noted for being rich in essential amino acids like lysine and tryptophan—often deficient in cereals—making its biological value comparable to animal-based proteins (Cowan, 1973; Quayam *et al.*, 1985) [5, 19]. Furthermore, its health-promoting properties, including its role in reducing risks of coronary heart disease and osteoporosis, have solidified its status as a functional food (Oyvind *et al.*, 2006) [17].

Despite this potential, a critical research problem persists: Indian soybean productivity remains stagnated at an average of 1179 kg/ha (Anon., 2025b). This yield gap is primarily driven by the rapid physiological deterioration of seed vigor, exacerbated by environmental sensitivity and poor storage capabilities (Calvino *et al.*, 2003 and Tatic *et al.*, 2012) [3, 24]. The crisis is further intensified by erratic climatic shifts; unseasonal rainfall during the *kharif* harvest frequently compromises seed integrity, making the production of high-quality planting material a recurring struggle for farmers. Consequently, off-season (summer) seed production has emerged as a vital contingency strategy to ensure a resilient and high-quality seed supply chain.

To resolve these productivity barriers, this study proposes a multi-pronged solution through integrated nutrient management. By leveraging biofertilizers like *Rhizobium* and Phosphorus

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Solubilizing Bacteria (PSB), we can naturally augment root development and nitrogen fixation (Prakash, 2001 and Saxena *et al.*, 2013) ^[18, 21]. When coupled with the precision of nanotechnology-which facilitates the synchronized, slow release of nutrients-we can drastically improve nutrient use efficiency (Meena *et al.*, 2021 and Jyothi and Hebsur, 2017) ^[16, 12]. Given the urgent need for robust seed material, the present study was undertaken to examine the synergistic effect of biofertilizers and nano-fertilizers on enhancing the seed yield and quality parameters of off-season soybean.

Materials and Methods

Two different experiments were carried out during Summer 2025 at the Seed Testing Laboratory, Department of Seed Science and Technology, JAU, Junagadh for laboratory experiment and Sagdividi Farm, Department of Seed Science and Technology, JAU, Junagadh for field experiment. Genetically pure seeds of variety Gujarat Soybean-4 (GS-4) were obtained from Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh.

In the investigation, two factor were assessed: the seed treatment of biofertilizers [S₁: (*Rhizobium*), S₂: (PSB), S₃: (KMB), S₄: (ZSB), S₅: (SOB) and S₆: (NPK consortia)] and nano-fertilizers foliar spray: [F₁: (4% Nano Urea), F₂: (Nano DAP) and F₃: (Nano Zn)] along with absolute control. The experiment was conducted with three replications at 45 × 10 cm spacing, with a gross plot size of 27 × 20 m² and a net plot size of 25 × 18 m². All the seeds are treated with different biofertilizers solution at dose of 10 ml/kg of seeds as per treatments combination and dry at room temperature. The sowing of seeds was done on 18th February, 2025. Foliar applications were administered twice, at 30 and 45 days after sowing (DAS). The treatments consisted of Nano Urea and Nano DAP applied at a concentration of 5 ml/L, while Nano Zn was applied at a rate of 5 g per 15 L of water.

The laboratory germination test was conducted as per ISTA (ISTA, 2015) ^[9] procedure by adopting between paper method. 100 seeds in four replications were taken at random from the seed lot of each treatment, placed uniformly on germination paper and kept in the control environment, where the temperature was maintained at 25 ± 0.50°C with 85 per cent relative humidity. The final counts were made on the 8th day of the germination test for normal seedlings and germination was expressed in percentage. Ten normal seedlings were selected randomly from the germination paper (B.P) on final day of counting germination and root and shoot length were measured from the tip of primary root to the tip of shoot. The mean root and shoot length were expressed in centimeters. Seedling length was measured by adding root and shoot length in centimeters. To record seedling fresh weight ten seedlings were counted, cut free from their cotyledon and weighted while still moist. Their weights were recorded in milligram. These seedlings were kept in a hot air oven for 24 hours at a temperature of 100°C (Gupta, 1993) ^[8]. The weight of the dried seedlings was recorded and expressed in milligram. Seedling vigour index-I and II were computed using following formula suggested by Abdul-Baki and Anderson and mean values were expressed in the whole number.

Vigour index I = Germination (%) × Seedling length (cm)

Vigour index II = Germination (%) × Seedling dry weight (mg)

The laboratory data were analyzed statistically adopting the procedure described by Cochran and Cox.

The following parameters were recorded for the field study: days to 50% flowering, days to maturity, plant height at maturity (cm), number of clusters per plant, number of pods per plant, number of pods per cluster, number of seeds per pod, number of seeds per

plant, biological yield per plant (g), seed yield per plant (g), test weight (g) and harvest index (%). Five selected plants were tagged from each replication treatment for recording observations. The mean of five plants for each character was used for statistical analysis. Observations were recorded at the maturity stage of plant growth on all the quantitative characters. The experimental data was analyzed statistically by adopting a randomized block design (Factorial) described as per the standard methods. A randomized block design (Factorial) ANOVA was used to assess treatment effects (Cochran and Cox, 1957) ^[4].

Results and Discussion

The results of laboratory observations are depicted in Figure 1 and Table 1-3. Irrespective of foliar spraying, seed treatments significantly influenced all studied characters except for the harvest index (%). Seeds treated with PSB (S₂) recorded significantly higher values for plant height at maturity (22.98 cm), number of clusters per plant (9.58), number of pods per plant (25.04), number of pods per cluster (2.97), number of seeds per pod (2.65), number of seeds per plant (63.41), biological yield per plant (11.92 g), seed yield per plant (5.99 g) and test weight (10.11 g). Furthermore, this treatment optimized crop phenology by reducing the days to 50% flowering (37.56 days) and days to maturity (99.67 days) compared to the control and other bio-inoculants (Meena *et al.*, 2023; Singh *et al.*, 2025; Solanki *et al.*, 2025) ^[15, 22, 23].

The superior efficacy of PSB is attributed to its ability to solubilize native and applied insoluble phosphorus through the production of organic acids. This enhances phosphorus availability, which is critical for robust root development and overall plant metabolism. While the NPK consortia performed at par due to its synergistic action in providing multiple nutrients, *Rhizobium* showed a comparatively lower response; its primary role in nitrogen fixation alone may not sufficiently meet the balanced nutrient requirements of the crop during critical growth stages.

Similarly, irrespective of seed treatments, foliar spraying resulted in significant differences across all parameters. Nano DAP (F₂) foliar spray achieved significantly higher results for plant height (23.24 cm), clusters per plant (9.98), pods per plant (25.68), pods per cluster (3.31), seeds per pod (2.66), seeds per plant (69.50), biological yield (12.59 g), seed yield (6.82 g), test weight (10.41 g) and harvest index (54.50%). It also reduced the time to 50% flowering (37.61 days) and maturity (99.00 days) compared to other treatments (Khemshetty *et al.*, 2024; Yadav *et al.*, 2024; Saqib *et al.*, 2025) ^[13, 26, 20].

The superior performance of Nano DAP in enhancing seed yield and its attributes is due to its role in promoting faster and more uniform nutrient uptake. By stimulating cell division and elongation, Nano DAP encourages more vigorous flowering, fruit set and seed development, ultimately resulting in bolder seeds and higher yield, germination and vigour indices. In contrast, Nano Urea and Nano Zn address only specific nitrogen or micronutrient needs, making their individual effects more limited. Consequently, the balanced nutrition provided by Nano DAP leads to enhanced dry matter partitioning and superior crop productivity.

The interaction between biofertilizer seed treatments and nano-fertilizer foliar applications was statistically non-significant for seed yield and most yield attributes, with the specific exception of the number of clusters per plant. This lack of interaction suggests that the individual effects of seed treatments on the studied characters are independent of the foliar spray applications and vice versa; the two factors do not influence each other's

physiological impact for the majority of parameters. However, for the number of clusters per plant, a significant interaction was observed, indicating that both factors exert a mutual influence on this particular character.

Furthermore, the contrast analysis between the absolute control and the remaining treatments revealed significant differences across seed yield per plant and all associated attributes. The absolute control consistently recorded the lowest values for all studied parameters when compared to the mean of all other treatment combinations. These findings align with those of Jaga and Sharma (2015) ^[10], underscoring the necessity of external nutrient supplementation through biofertilizers or nano-fertilizers to achieve optimized crop productivity.

The results of laboratory observations are depicted in Figure 1 and Table 4 and 5. Irrespective of the nano-fertilizer foliar spray application, seed treatment with biofertilizers significantly influenced all studied seed quality parameters. Specifically, seeds treated with PSB (S₂) recorded significantly higher values for

germination (86.56%), shoot length (4.43 cm), root length (3.93 cm), seedling length (8.36 cm), seedling dry weight (304.78 mg), seedling vigour index I (724.88) and seedling vigour index II (26442.67). Similarly, in the case of foliar spraying, the application of Nano DAP (F₂) resulted in significantly higher germination (89.22%), shoot length (4.51 cm), root length (4.13 cm), seedling length (8.64 cm), seedling dry weight (315.72 mg), seedling vigour index I (770.70) and seedling vigour index II (28185.06) (Dalvi *et al.*, 2021; Javed *et al.*, 2023 and Thakur *et al.*, 2024) ^[6, 11, 25]. Statistical analysis further revealed that the interaction effect between biofertilizer seed treatments and nano-fertilizer foliar spray applications was non-significant for these seed quality parameters, suggesting that each factor acted independently. Furthermore, the contrast analysis of the control vs. all other treatments showed a significant difference across all seed quality parameters studied, confirming the efficacy of the tested nutritional interventions over the absolute control.

Table 1: Effect of seed treatment of biofertilizers, foliar spray of nano-fertilizers and their interaction on 50 per cent flowering, days to maturity, plant height at maturity (cm) and number of clusters per plant in soybean

Treatments/Characters	Days to 50 per cent flowering	Days to maturity	Plant height at maturity (cm)	Number of clusters per plant
Seed treatment of biofertilizer (S)				
S ₁	38.56	101.11	21.33	9.08
S ₂	37.56	99.67	22.98	9.58
S ₃	38.89	100.44	20.62	8.63
S ₄	38.44	101.33	21.38	8.49
S ₅	39.11	100.78	21.31	9.02
S ₆	38.33	99.78	22.67	8.80
S. Em.±	0.41	0.50	0.59	0.31
C.D. at 5%	1.18	1.44	1.70	0.89
Foliar spray of nano-fertilizer (F)				
(F ₁)	38.94	101.78	21.03	8.77
(F ₂)	37.61	99.00	23.24	9.98
(F ₃)	38.89	100.78	20.87	8.06
S. Em.±	0.29	0.36	0.42	0.22
C.D. at 5%	0.83	1.02	1.20	0.63
S x F				
S. Em.±	0.71	0.87	1.03	0.54
C.D. at 5%	NS	NS	NS	1.55
Control vs Rest				
Control	40.00	106.00	18.73	7.07
Rest	38.48	100.52	21.71	8.93
S. Em.±	0.52	0.63	0.75	0.39
C.D. at 5%	1.49	1.81	2.14	1.13
CV%	3.20	1.50	8.25	10.60

Table 2: Effect of seed treatment of biofertilizers, foliar spray of nano-fertilizers and their interaction on number of pods per plant, number of pods per cluster, number of seeds per pod and number of seeds per plant in soybean

Treatments/Characters	Number of pods per plant	Number of pods per cluster	Number of seeds per pod	Number of seeds per plant
Seed treatment of biofertilizer (S)				
S ₁	22.40	2.87	2.46	57.77
S ₂	25.04	2.97	2.65	63.41
S ₃	22.58	2.85	2.47	60.53
S ₄	23.00	2.76	2.47	56.20
S ₅	22.73	2.82	2.45	55.11
S ₆	24.00	3.07	2.55	60.31
S. Em.±	0.83	0.10	0.07	1.76
C.D. at 5%	2.37	0.28	0.19	5.06
Foliar spray of nano-fertilizer (F)				
(F ₁)	22.66	2.75	2.44	56.02
(F ₂)	25.68	3.31	2.66	69.50
(F ₃)	21.54	2.61	2.43	51.14
S. Em.±	0.58	0.07	0.05	1.25
C.D. at 5%	1.68	0.20	0.13	3.58

S x F				
S. Em.±	1.43	0.17	0.11	3.05
C.D. at 5%	NS	NS	NS	NS
Control vs Rest				
Control	17.07	2.35	2.25	45.00
Rest	23.29	2.89	2.51	58.89
S. Em.±	1.04	0.12	0.08	2.22
C.D. at 5%	2.99	0.35	0.24	6.36
CV%	10.81	10.19	7.96	9.09

Table 3: Effect of seed treatment of biofertilizers, foliar spray of nano-fertilizers and their interaction on biological yield per plant (g), seed yield per plant (g), test weight (g) and harvest index (%) in soybean

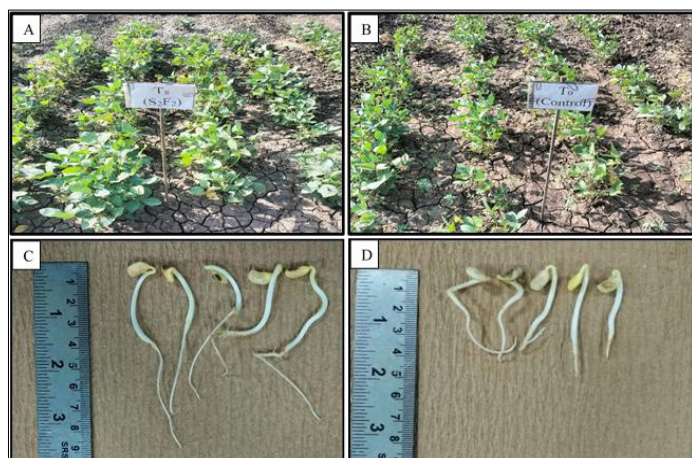
Treatments/Characters	Biological yield per plant (g)	Seed yield per plant (g)	Test weight (g)	Harvest index (%)
Seed treatment of biofertilizer (S)				
S ₁	10.64	5.84	9.46	56.36
S ₂	11.92	5.99	10.11	48.78
S ₃	10.53	5.18	9.25	49.29
S ₄	10.58	5.59	9.16	53.08
S ₅	10.39	5.30	9.28	51.33
S ₆	11.56	5.90	9.77	49.39
S. Em.±	0.37	0.19	0.26	2.16
C.D. at 5%	1.07	0.55	0.73	NS
Foliar spray of nano-fertilizer (F)				
(F ₁)	10.06	5.33	8.97	52.40
(F ₂)	12.59	6.82	10.41	54.40
(F ₃)	10.16	4.75	9.14	47.32
S. Em.±	0.26	0.14	0.18	1.53
C.D. at 5%	0.76	0.39	0.52	4.38
S x F				
S. Em.±	0.65	0.33	0.44	3.74
C.D. at 5%	NS	NS	NS	NS
Control vs Rest				
Control	7.80	3.65	8.58	43.33
Rest	10.94	5.63	9.51	51.37
S. Em.±	0.47	0.24	0.32	2.72
C.D. at 5%	1.35	0.69	0.92	7.79
CV%	10.39	10.37	8.10	12.71

Table 4: Effect of seed treatment of biofertilizers, foliar spray of nano-fertilizers and their interaction on germination (%), shoot length (cm), root length (cm) and seedling length (cm) in soybean

Treatments/Characters	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling length (cm)
Seed treatment of biofertilizer (S)				
S ₁	83.56	3.96	3.51	7.47
S ₂	86.56	4.43	3.93	8.36
S ₃	82.78	3.95	3.77	7.72
S ₄	86.11	3.72	3.65	7.37
S ₅	85.44	3.72	3.56	7.28
S ₆	83.78	3.93	3.60	7.62
S. Em.±	0.93	0.06	0.06	0.09
C.D. at 5%	2.66	0.18	0.16	0.26
Foliar spray of nano-fertilizer (F)				
(F ₁)	83.67	3.76	3.46	7.22
(F ₂)	89.22	4.51	4.13	8.64
(F ₃)	81.22	3.58	3.43	7.05
S. Em.±	0.66	0.05	0.04	0.07
C.D. at 5%	1.88	0.13	0.12	0.19
S x F				
S. Em.±	1.61	0.11	0.10	0.16
C.D. at 5%	NS	NS	NS	NS
Control vs Rest				
Control	75.67	2.79	2.44	5.23
Rest	84.70	3.95	3.67	7.64
S. Em.±	1.65	0.11	0.10	0.16
C.D. at 5%	4.73	0.33	0.29	0.47
CV%	3.31	4.96	4.78	3.69

Table 5: Effect of seed treatment of biofertilizers, foliar spray of nano-fertilizers and their interaction on seedling dry weight (mg), seedling vigour index- I and seedling vigour index- II in soybean

Treatments/Characters	Seedling dry weight (mg)	Seedling vigour index I	Seedling vigour index II
Seed treatment of biofertilizer (S)			
S ₁	290.89	632.51	24383.89
S ₂	304.78	724.88	26442.67
S ₃	297.22	641.87	24427.22
S ₄	277.67	635.51	23929.67
S ₅	282.11	623.40	23582.11
S ₆	293.11	647.53	24662.00
S. Em.±	3.97	10.41	422.90
C.D. at 5%	11.37	29.81	1210.72
Foliar spray of nano-fertilizer (F)			
(F ₁)	280.94	604.96	23514.72
(F ₂)	315.72	770.70	28185.06
(F ₃)	276.22	577.19	22014.00
S. Em.±	2.81	7.36	299.03
C.D. at 5%	8.04	21.08	856.11
S x F			
S. Em.±	6.88	18.04	732.48
C.D. at 5%	NS	NS	NS
Control vs Rest			
Control	211.67	395.23	16014.00
Rest	290.67	650.95	24571.26
S. Em.±	7.07	18.53	752.55
C.D. at 5%	20.73	53.05	2154.50
CV%	4.15	4.90	5.26

**Fig 1:** Comparative effect of seed treatment with PSB and foliar application of Nano-DAP on crop growth and seedling vigor.

Conclusion

The findings revealed that seed treatment with PSB and foliar spraying with nano DAP significantly enhanced days to 50 percent flowering, days to maturity, plant height, various yield components and quality parameters. The interaction between different seed treatments and foliar spraying treatments was not statistically significant except for the number of clusters per plant, which recorded a substantial difference. This indicates that seed treatment of biofertilizers and foliar spraying of nano-fertilizers had independent effects on most traits. These seed treatments provide a cost-effective and environmentally sustainable alternative to conventional chemical inputs, making nutrients easily available for the plant. Since PSB and Nano DAP are highly efficient and promote targeted nutrient delivery, their use can optimize input costs while enhancing productivity. Overall,

looking at the result, it could be suggested that soybean seeds treated with PSB and foliar spraying of Nano DAP will give a higher seed yield and its quality parameters independently. Future studies should assess their long-term impact on soil health, microbial activity and crop yield while exploring their integration with eco-efficient farming practices and validation across agro-climatic regions.

Acknowledgements

The authors thank the College of Agriculture, Junagadh Agricultural University, for providing the necessary infrastructure and resources.

References

- Anonymous. Soybean outlook, January 2025. Hyderabad: Agricultural Market Intelligence Centre, PJTSAU; 2025.
- Anonymous. Unified portal for agricultural statistics. Department of Agriculture and Farmers Welfare; 2025.
- Calvino PA, Sadras VO, Andrade FH. Quantification of environmental and management effects on the yield of late-sown soybean. *Field Crops Research*. 2003;83(1):67–77.
- Cochran WG, Cox GM. *Experimental designs*. 2nd ed. New York: Wiley; 1957.
- Cowan JC. *Proceedings and products*. In: Caldwell BE, editor. *Soybean: Improvement, production and uses*. Madison (WI): American Society of Agronomy; 1973. p. 681.
- Dalvi AA, Kalyankar SV, Gaikwad RA, Rathod PS. Effect of bioagent and seed coating on yield and seed quality parameters in soybean (*Glycine max* L.). *Journal of Pharmacognosy and Phytochemistry*. 2021;10(1):1187–1189.
- Gopalan C, Rama Sastry BV, Balasubramanian SC. *Nutritive value of Indian foods*. Revised and updated by Narasinga Rao BS, Deosthale YG, Pant KC. Hyderabad: National Institute of Nutrition, Indian Council of Medical Research; 1989.
- Gupta PC. Seed vigour testing. In: *Handbook of seed testing*.

- New Delhi; 1993. p. 242–249.
9. ISTA. International rules for seed testing. Bassersdorf: International Seed Testing Association; 2015.
 10. Jaga PK, Sharma S. Effect of bio-fertilizer and fertilizers on productivity of soybean. *Annals of Plant and Soil Research*. 2015;17(2):171–174.
 11. Javed S, Ismail S, Dhamak AL, More SS. Effect of microbial consortia inoculation and chemical fertilizers on growth parameter and nodulation of soybean (*Glycine max* L. Merrill) and chickpea (*Cicer arietinum* L.). *International Journal of Plant and Soil Science*. 2023;35(22):779–790.
 12. Jyothi TV, Hebsur NS. Effect of nanofertilizers on growth and yield of selected cereals: A review. *Agricultural Reviews*. 2017;38(2):112–120.
 13. Khemshetty A, Patil DH, Rathod PS, Patil AS, Basavaraj K. Studies on Nano DAP on growth, yield and quality of chickpeas under rainfed conditions of Northeastern Dry Zone of Karnataka. *Journal of Experimental Agriculture International*. 2024;46(3):139–145.
 14. Kumar A, Lal GM, Mishra PK. Genetic variability and character association for yield and its components in soybean. *Annals of Plant and Soil Research*. 2013;16(1):48–52.
 15. Meena K, Meena RK, Meena DS, Meena BS, Meena CB, Yadav VK, Jadon CK. Effect of inorganic fertilizers and biofertilizers on growth and nodulation of soybean (*Glycine max* (L.) Merrill). *The Pharma Innovation Journal*. 2023;12(7):1752–1755.
 16. Meena RH, Jat G, Jain D. Impact of foliar application of different nano-fertilizers on soil microbial properties and yield of wheat. *Journal of Environmental Biology*. 2021;42(2):302–308.
 17. Oyvind M, Kenneth A, Markham R. Flavonoids: Chemistry, biochemistry and applications. Boca Raton (FL): CRC Press Taylor and Francis Group; 2006.
 18. Prakash A. Effect of rhizobium on nitrogen fixation and yield of soybean. *Journal of Plant Nutrition*. 2001;24(5):811–824.
 19. Quayam A, Rao MSS, Violet K. Soybean: A miracle oilseed crop—its prospects and constraints in Bihar plateau. In: *Proceedings of Oilseed Production Constraints and Opportunities*. 1985. p. 219–232.
 20. Saqib A, Manuja S, Kumar N, Sharma RP, Mujahed BA, Thakur D, Mridula. Effect of nitrogen and phosphorus levels and Nano-DAP application on growth and yield of soybean (*Glycine max* (L.) Merr.). *Himachal Journal of Agricultural Research*. 2025;51(1):88–93.
 21. Saxena J, Minaxi, Chandra S, Nain L. Synergistic effect of phosphate solubilizing rhizobacteria and arbuscular mycorrhiza on growth and yield of wheat plants. *Journal of Soil Science and Plant Nutrition*. 2013;13(2):511–525.
 22. Singh S, Sahu RK, Mitra NG, Singh S, Parmar B, Raghuwanshi S, *et al.* Impact of microbial consortia on growth, yield and nutrient uptake of soybean in vertisols of central India. *Plant Archives*. 2025;25(2):2579–2587.
 23. Solanki AC, Gurjar NS, Sharma S. Co-inoculation of non-symbiotic bacteria *Bacillus* and *Paraburkholderia* can improve the soybean yield, nutrient uptake and soil parameters. *Molecular Biotechnology*. 2025;67:3041–3053.
 24. Tatic M, Balesevic-Tubic S, Dordevic V, Nikolic Z, Dukic V, Vujakovic M, *et al.* Soybean seed viability and changes of fatty acids content as affected by seed aging. *African Journal of Biotechnology*. 2012;11(45):10310–10316.
 25. Thakur D, Saqib A, Kumar N, Manuja S, Sharma GD, Kumar A, *et al.* Effect of Nano DAP on germination and seedling growth of different crops. *Biological Forum – An International Journal*. 2024;16(12):24–28.
 26. Yadav A, Babu S, Krishnan P, Kaur B, Bana RS, Chakraborty D, *et al.* Zinc oxide and ferric oxide nanoparticles combination increase plant growth, yield and quality of soybean under semi-arid region. *Chemosphere*. 2024;352:141432.