International Journal of Agriculture and Food Science 2025; 7(9): 889-894

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(9): 889-894
www.agriculturaljournals.com
Received: 12-06-2025
Accepted: 14-07-2025

Mohit S Vasave
M.Sc. (Agri.) Student, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

Dattatraya R Murumkar
Associate Professor of Plant Pathology at College of Agriculture, Karad, Tal. Karad, Satara, Maharashtra, India

Ashok C Jadhav
Junior Mycologist AICRP on Mushroom College of Agriculture, Pune, Maharashtra, India

Vilas M Karade
Head of Section of Plant Pathology and Agriculture Microbiology, College of Agriculture, Pune, Maharashtra, India

Deepak D Sawale
Senior Research Officer AICRP on PHET & Associate Professor (Soil Science) Regional Sugarcane and Jaggery Research Station, Kolhapur, Maharashtra, India

Jayant A Pradhan
M.Sc. (Agri.) Student, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

Corresponding Author:
Mohit S Vasave
M.Sc. (Agri.) Student, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

Exploring the effect of seed biopriming with MPKV bacterial consortium on macronutrient uptake, soil fertility and economic returns in cowpea (*Vigna unguiculata* (L.) Walp)

Mohit S Vasave, Dattatraya R Murumkar, Ashok C Jadhav, Vilas M Karade, Deepak D Sawale and Jayant A Pradhan

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i9l.840

Abstract
A field experiment was carried out during *kharif* 2024 at the College of Agriculture, Pune to evaluate the influence of seed biopriming with the MPKV bacterial consortium on growth, nutrient uptake, and yield performance of cowpea. The consortium, formulated at Mahatma Phule Krishi Vidyapeeth, comprises beneficial microbial strains capable of nitrogen fixation and phosphorus solubilization, thereby improving nutrient availability in the rhizosphere. Findings revealed that seed biopriming combined with 75% of the recommended fertilizer dose (RDF) proved most effective. This treatment achieved significantly higher germination (95.43%), plant height (47.53 cm at flowering and 63.60 cm at harvest), root length (17.93 cm and 22.30 cm), as well as maximum shoot (12.18 g plant^{-1}) and root dry matter (2.63 g plant^{-1}). Yield parameters were also enhanced, including number of nodules (32 plant^{-1}), pods per plant (43.33), 1000-seed weight (132.60 g), and seed yield (11.92 q ha^{-1}). In addition, greater uptake of nitrogen, phosphorus, and potassium (90.07, 17.54, and 45.15 kg ha^{-1}, respectively) and increased populations of Rhizobium, PSB, and KMB were recorded. Notably, the performance of the consortium with 75% RDF was statistically comparable to that with 100% RDF, indicating that 25% of nitrogen and phosphorus fertilizers can be saved without compromising yield. Hence, seed biopriming with the MPKV bacterial consortium emerges as a sustainable strategy for improving cowpea productivity, nutrient efficiency, and soil microbial activity, while reducing reliance on chemical fertilizers.

Keywords: Cowpea, seed biopriming, MPKV bacterial consortium, macronutrient uptake, soil fertility, economic return

1. Introduction
In India, grain legumes, particularly pulses, play a vital role in agriculture and serve as a primary source of dietary protein, fulfilling the nutritional needs of the predominantly vegetarian population. They improve soil fertility through nitrogen fixation, addition of organic matter, secretion of growth-promoting substances, and act as fodder crop for livestock. Pulses also adapt well to rainfed farming and require fewer inputs, making them an economically viable crop. Globally, in 2022 pulses occupied about 959.68 lakh ha with production of 973.92 lakh tones and productivity of 1015 kg/ha. India, with more than 35 million ha under pulses, ranks first in area (38%) and production (28%). In Maharashtra, 44.05 lakh ha was under pulses with 38.22 lakh tonnes production during 2021-22 (Directorate of Pulses Development, GOI, 2022).
Cowpea (*Vigna unguiculata* (L.) Walp.) is an annual legume crop that reproduces through self-pollination. It belongs to the family *Leguminaceae* and has a diploid chromosome number of 2*n* = 22. Although originally native to India, tropical and central Africa are regarded as its secondary centre of origin. Cowpea is a low-resource crop, needing less labor and water than other legumes. Its short duration enables multiple harvests each year, act as green manure crop, boosting land use and income, Moreover, its ability to thrive in different agro-climatic conditions, ensuring stable income for marginal farmers. (Choudhary and Kumar 2013) [5].

The national mean productivity of cowpea is approximately 607 kg per hectare, according to ICAR (2020) which is relatively insufficient. Key factors contributing to the low yield of cowpea are cultivation on infertile lands, inefficient crop management, scarcity of resources available to farmers, and slow adoption of modern farming methods.

Bio-priming is a biological seed treatment that combines controlled hydration with inoculation using beneficial microbes. This technique enhances seed viability, germination, seedling vigor, and plant growth, while also providing protection against diseases and improving crop yield. Commonly, microbial inoculant like, PGPR's beneficial bacteria or fungi are employed for seed bio-priming. Seed bio-priming is an emerging method of seed treatment that facilitates faster and more uniform germination, leading to improved seedling vigor and plant growth. Moeinzadeh *et al*., 2010) [10] Seed bio-priming serves as an effective alternative to conventional seed treatments, as beneficial microbes colonize the root surface, develop biofilms, and safeguard plants against soil-borne pathogens throughout their growth cycle (Singh *et al*., 2016) [15]. Seed biopriming with plant growth-promoting rhizobacteria, including *Bacillus megaterium* and *Azospirillum brasilense*, together with biocontrol organisms such as *Trichoderma harzianum* and *Pseudomonas fluorescens*, resulted in a significant rise in defence enzyme activity, establishing its utility as a sustainable strategy for managing damping-off disease (Rajendraprasad *et al*. 2017) [14]. Microorganisms promote plant development by releasing compounds that enhance seed germination and stimulate root formation, such as auxins, abscisic acid, gibberellic acid, cytokinins, and ethylene (Santner *et al.,* 2009) [16].

2. Materials and Methods

Present investigation was carried out during *kharif* 2024 on the field of Biological Nitrogen Fixation Scheme and Department of Plant Pathology, College of Agriculture Pune.

2.1 Seeds: The seeds of cowpea variety *Phule Sonali* (PCP-1123) required for the experiment were obtained from the Pulses and Oilseed Crop Research and Training Centre, Pandharpur, Solapur.

2.2 Soil sampling: Soil samples were collected from the experimental plot before and after harvesting of the Cowpea for analysis of nutrient status of the soil. The collected soil samples were air dried, crushed in wooden mortar and pestle. Soil was sieved through a 2 mm sieve. Then the soil samples were analyzed for their chemical properties by using standard analytical methods.

2.3 Plant sampling: The plant samples for total N, P, and K analysis were collected separately from each treatment plot at the harvesting stage. The plant samples were then kept in paper bags and dried in a hot air oven at 70°C for 48 hours. The dried plant parts were finely grounded in a mixer. This fine powder was again dried in the oven at 60°C for a couple of hours and stored properly till the samples were used for chemical analysis of nutrients.

2.4 Collection of bacterial consortium: The required MPKV bacterial consortium and reference strain of *Pseudomonas fluorescens* and *Bacillus subtilis* was collected from the department of plant pathology and agriculture microbiology MPKV Rahuri.

2.5 Biopriming of seed with bacterial consortium: For the experiment, the bacterial consortium along with the reference strains of *Pseudomonas* and *Bacillus subtilis* were used as per treatments. A quantity of 25 g from each inoculant the consortium and the individual reference strains was measured and separately suspended in 1000 ml of water in beakers. Cowpea seeds were then immersed in these prepared solutions for a period of 12 hours prior to sowing. After soaking, the seeds were removed, air-dried under shade for about 30 minutes, and subsequently sown in the field.

2.6 Observation recorded: The observations on nutrient uptake by cowpea *viz*. Nitrogen, Phosphorous, Potassium; soil available nutrients *viz*. Nitrogen, Phosphorous, Potassium; Economic of cowpea.

2.7 Treatment details: The cowpea seeds were inoculated before sowing as T_1- Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF, T_2- Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF, T_3- Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF, T_4- Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF, T_5- Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF, T_6- Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF and T_7- Untreated control.

3. Result and Discussion

3.1 Inoculation Effect of Seed Biopriming with MPKV Bacterial Consortium on Nutrient Uptake by Cowpea at Harvest

3.1.1 Nitrogen Uptake

The results related to the nutrient uptake of cowpea by using MPKV bacterial consortium as seed treatment are reported. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest nitrogen uptake (90.07 kg ha^{-1}) over rest of the treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for nitrogen uptake (87.55 kg ha^{-1}) by cowpea at harvest. The untreated control plot recorded the lowest nitrogen uptake (45.24 kg ha^{-1}).

3.1.2 Phosphorus Uptake

The results related to the nutrient uptake of cowpea by using MPKV bacterial consortium as seed treatment are reported. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest phosphorus uptake (17.54 kg ha^{-1}) over rest of the treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for phosphorus uptake (16.79 kg ha^{-1}) by cowpea at harvest. The untreated control plot recorded the lowest phosphorus uptake (8.34 kg ha^{-1}).

3.1.3 Potassium Uptake
The results related to the nutrient uptake of cowpea by using MPKV bacterial consortium as seed treatment are reported. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest potassium uptake (45.15 kg ha^{-1}) over rest of the treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for potassium uptake (44.02 kg ha^{-1}) by cowpea at harvest. The untreated control plot recorded the lowest potassium uptake (19.18 kg ha^{-1}).

Seed biopriming with the MPKV bacterial consortium influenced nutrient uptake in cowpea because the beneficial microbes enhanced nitrogen fixation, phosphorus solubilization, and potassium mobilization. This improved root growth and microbial activity in the rhizosphere, leading to better availability and absorption of N, P and K at harvest. Similar findings were also reported by Bansal (2009) [2], Qureshi *et al.* (2011) [13], Argaw (2012) [1], Tarafder *et al.* (2016) [19], Shete *et al.* (2019) and Ghadge and Murumkar (2020) [6].

Table 1: Effect of seed biopriming with MPKV bacterial consortium on nutrient uptake (kg ha^{-1}) by cowpea at harvest

Tr. No.	Treatment details	Nutrient uptake (kg ha^{-1})		
		N	P_2O_5	K_2O
T_1	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	87.55	16.79	44.02
T_2	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	90.07	17.54	45.15
T_3	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	81.34	13.56	36.40
T_4	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	74.49	12.17	29.36
T_5	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	77.96	12.67	30.26
T_6	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	72.02	10.34	25.15
T_7	Untreated control	45.24	8.34	19.18
	SE$\pm$	0.90	0.28	0.79
	CD at 5%	2.78	0.86	2.44

3.2 Inoculation Effect of Seed Biopriming with MPKV Bacterial Consortium on Available NPK after Harvest in Soil

3.2.1 Available Nitrogen
After harvesting of cowpea, the soil was analysed to determine the availability of Nitrogen and the results are reported accordingly under the influence of seed biopriming with MPKV bacterial consortium. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest available nitrogen (205.51 kg ha^{-1}) in soil compared to the other treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for available nitrogen (193.01 kg ha^{-1}) after harvest in soil. The untreated control plot recorded lowest available nitrogen (122.14 kg ha^{-1}) after harvest in soil.

3.2.2 Available Phosphorus
After harvesting of cowpea, the soil was analyzed to determine the availability of Phosphorus, and the results are reported accordingly under the influence of seed biopriming with MPKV bacterial consortium. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest available phosphorus (30.19 kg ha^{-1}) in soil compared to the other treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for available phosphorus (28.90 kg ha^{-1}) after harvest in soil. The untreated control plot recorded lowest available phosphorus (16.21 kg ha^{-1}) after harvest in soil.

3.2.3 Available Potassium
After harvesting of cowpea, the soil was analyzed to determine the availability of Potassium, and the results are reported accordingly under the influence of seed biopriming with MPKV bacterial consortium. When comparing different inoculation treatment, T_2 i.e. seed biopriming with MPKV bacterial consortium + 75% RDF was found to be the most effective as it recorded significantly highest available potassium (115.73 kg ha^{-1}) in soil compared to the other treatments, however it was statistically at par with T_1 i.e. seed biopriming with MPKV bacterial consortium + 100% RDF for available potassium (112.37 kg ha^{-1}) after harvest in soil. The untreated control plot recorded lowest available potassium (76.53 kg ha^{-1}) after harvest in soil.

Seed biopriming with the MPKV bacterial consortium influenced the availability of NPK in soil after harvest because the microbes fixed atmospheric nitrogen, solubilized insoluble phosphorus, and mobilized potassium, thereby enriching the soil nutrient pool. Enhanced microbial activity maintained higher residual nutrients even after crop uptake, improving soil fertility for subsequent crops. Similar findings were also reported by Bansal (2009) [2], Qureshi *et al.* (2011) [13], Argaw (2012) [1], Tarafder *et al.* (2016) [19], Shete *et al.* (2019) and Ghadge and Murumkar (2020) [6].

Table 2: Effect of seed biopriming with MPKV bacterial consortium on available NPK (kg ha^{-1}) after harvest in soil

Tr. No.	Treatment details	Available nutrients (kg ha^{-1})		
		N	P_2O_5	K_2O
T_1	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	193.01	28.90	112.37
T_2	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	205.51	30.19	115.73
T_3	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	178.54	24.39	102.29
T_4	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	167.57	21.55	97.82
T_5	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	171.45	23.46	99.31
T_6	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	163.78	20.79	95.58
T_7	Untreated control	122.14	16.21	76.53
	SE±	7.66	0.43	1.60
	CD at 5%	23.62	1.33	4.93

3.3 Inoculation Effect of Seed Biopriming with MPKV Bacterial Consortium on Fertilizer Nitrogen and Phosphorus Economy of Cowpea

In a recent study, different treatments were examined to assess their effects on grain yield and economic returns, and multiple approaches were analyzed and compared. When comparing different seed inoculation treatments, T_1 i.e. seed biopriming with an MPKV bacterial consortium at 25g per kilograms of seed in 1 litre of water for 12 hours before sowing, combined with recommended dose of fertilizers which is 100% (RDF). This treatment resulted in a grain yield of 11.05 quintals per hectare, a gross monetary return of ₹66,300 per hectare, a cost of cultivation of ₹39,621 per hectare and a net monetary return of ₹26,679 per hectare, with a benefit-to-cost ratio of 1.67. Treatment T_2 which also used the MPKV bacterial consortium but with 75% RDF, yielded slightly more at 11.92 q ha^{-1}. It produced a gross return of ₹71,520 per hectare, with a cultivation cost of ₹38,746 per hectare, leading to a net return of ₹ 32,774 per hectare and B:C ratio of 1.85. Lastly, the untreated control yielded 6.11 q ha^{-1}, with a gross return of ₹36,660 per hectare, a cultivation cost of ₹36,065 per hectare, a net return of ₹595 per hectare, and B:C ratio of 1.02. Overall, treatments involving the MPKV bacterial consortium in combination with higher RDF levels consistently resulted in significantly higher grain yields and improved economic returns compared to treatments utilizing reference strains or lower RDF levels.

Table 3: Inoculation Effect of Seed Biopriming with MPKV Bacterial Consortium on Fertilizer Nitrogen and Phosphorus Economy of Cowpea

Tr. No.	Treatment details	Grain yield (q ha^{-1})	Gross monetary return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetary return (₹ ha^{-1})	B:C ratio
T_1	Seed biopriming with MPKV bacterial consortium @ 25g kg -1 seed in 1 litre water for 12 hrs. before sowing + 100% RDF	11.05	66300	39621	26679	1.67
T_2	Seed biopriming with MPKV bacterial consortium @ 25g kg -1 seed in 1 litre water for 12 hrs. before sowing + 75% RDF	11.92	71520	38746	32774	1.85
T_3	Seed biopriming with MPKV bacterial consortium @ 25g kg -1 seed in 1 litre water for 12 hrs. before sowing + 50% RDF	10.38	62280	37883	24397	1.64
T_4	Seed biopriming with reference strain @ 25 g kg-1 seed in 1 litre water for 12 hrs. before sowing + 100% RDF	10.19	61140	39621	21519	1.54
T_5	Seed biopriming with reference strain @ 25g kg -1 seed in 1 litre water for 12 hrs. before sowing + 75% RDF	10.30	61800	38746	23054	1.60
T_6	Seed biopriming with reference strain @ 25g kg -1 seed in 1 litre water for 12 hrs. before sowing + 50% RDF	9.74	58440	37883	20557	1.54
T_7	Untreated control	6.11	36660	36065	595	1.02

3.4 Inoculation Effect of Seed Biopriming with MPKV Bacterial Consortium on Microbial Population of *Rhizobium*, PSB and KMB at Flowering Stage of Cowpea:

At the flowering stage, fresh root nodules were assessed for rhizobial populations, while soil samples were examined for phosphate-solubilizing bacteria (PSB) and potash-mobilizing bacteria (KMB). The data collected were analyzed and presented. Among the different inoculation treatments, T_2 (seed biopriming with the MPKV bacterial consortium + 75% RDF) proved most effective, recording the highest populations of Rhizobium, PSB, and KMB (33.33, 26.33, and 25.67 × 10^6 cfu g^{-1} soil, respectively) at flowering. This treatment was statistically comparable to T_1 (seed biopriming with the MPKV bacterial consortium + 100% RDF), which recorded 30.00, 23.67, and 23.00 × 10^6 cfu g^{-1} soil, respectively. The increase in Rhizobium, PSB, and KMB populations under seed biopriming treatment can be attributed to enhanced root colonization, improved nutrient cycling, and active symbiotic interactions, along with suppression of harmful microbes, which collectively favored the survival and proliferation of beneficial microorganisms. These observations are in agreement with the findings of Cao *et al.* (2016) [3] and Shete *et al.* (2019) [17].

Table 4: Effect of seed biopriming with MPKV bacterial consortium on microbial population of *Rhizobium*, PSB and KMB at flowering stage of cowpea

Tr. No.	Treatment details	Microbial population at flowering (x 10^6)		
		Rhizobium	PSB	KMB
T_1	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	30.00	23.67	23.00
T_2	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	33.33	26.33	25.67
T_3	Seed biopriming with MPKV bacterial consortium @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	24.67	21.33	20.33
T_4	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 100% RDF	17.33	17.67	18.67
T_5	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 75% RDF	20.33	19.00	20.33
T_6	Seed biopriming with reference strain @ 25g kg^{-1} seed in 1 litre water for 12 hrs. before sowing + 50% RDF	11.33	15.33	16.33
T_7	Untreated control	9.67	10.00	10.33
	SE$\pm$	1.12	0.88	1.11
	CD at 5%	3.45	2.71	3.41

4. Conclusion

The present investigation clearly demonstrated that seed biopriming of cowpea with the MPKV bacterial consortium significantly improved nutrient uptake, soil fertility, yield performance, microbial population, and economic returns over the untreated control. The treatment with seed biopriming + 75% RDF (T_2) proved to be most effective, as it recorded highest uptake of nitrogen, phosphorus, and potassium, enhanced residual availability of NPK in soil, and sustained higher beneficial microbial populations at flowering. This treatment also resulted in superior grain yield and net monetary return with a higher benefit:cost ratio compared to 100% RDF or control, thereby highlighting its fertilizer economy potential.

The findings suggest that integration of MPKV bacterial consortium through seed biopriming with 75% RDF can effectively reduce chemical fertilizer requirement without compromising yield, while simultaneously improving soil health and microbial activity. Thus, MPKV bacterial consortium-based seed biopriming technology offers a sustainable and eco-friendly approach for enhancing productivity, profitability, and soil fertility in cowpea cultivation systems.

References

1. Argaw A. Evaluation of co-inoculation of *Bradyrhizobium japonicum* and phosphate solubilizing *Pseudomonas* spp. effect on soybean (*Glycine max* L. Merr.) in Assossa area. J Agric Sci Technol. 2012;14:213-24.
2. Bansal RK. Synergistic effect of *Rhizobium*, PSB and PGPR on nodulation and grain yield of mung bean. J Food Legumes. 2009;22(1):37-9.
3. Cao ND, Duong BS, Nguyen BT, Phan VHL. Effects of rhizobia and phosphate-solubilizing bacteria on soybean (*Glycine max*) cultivated on ferrosols of Daklak province, Vietnam. World J Pharm Sci. 2016;5(4):318-33.
4. Chapman HD, Pratt PF. Methods of analysis for soils, plants, and waters. Berkeley, Calif.: Univ Div Agr Sci; 1961. 309 p.
5. Choudhary VK, Kumar PS. Nutrient budgeting, economics and energetics of cowpea under potassium and phosphorus management. SAARC J Agric. 2013;11(2):129-40.
6. Ghadge JR, Murumkar DR, Shete MH. Development of microbial consortia of nitrogen fixing, phosphate solubilizing and potash mobilizing bacteria for optimizing nutrient supplementation to soybean. Int J Curr Microbiol Appl Sci. 2020;9(7):1889-902.
7. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India; 1973. p. 134-9.
8. Jaybhay SA, Taware SP, Philips V. Microbial inoculation of *Rhizobium* and phosphate-solubilizing bacteria along with inorganic fertilizers for sustainable yield of soybean [*Glycine max* (L.) Merril]. J Plant Nutr. 2017;40(15):2209-16.
9. Knudsen D, Peterson GA, Pratt PF. Lithium, sodium, and potassium. In: Methods of soil analysis: Part 2 chemical and microbiological properties. Madison: ASA; 1982. p. 225-46.
10. Moeinzadeh A, Sharif-Zadeh F, Ahmadzadeh M, Tajabadi FH. Biopriming of sunflower (*Helianthus annuus* L.) seed with *Pseudomonas fluorescens* for improvement of seed invigoration and seedling growth. Aust J Crop Sci. 2010;4(7):564-70.
11. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with $NaHCO_3$. USDA Circ. 1954;939.
12. Parkinson JA, Allen SE. A wet oxidation procedure suitable for determination of N and mineral nutrients in biological materials. Commun Soil Sci Plant Anal. 1975;6(1):6-11.
13. Qureshi MA, Shair MA, Iqbal A, Ahtar N, Khan A. Co-inoculation of phosphate solubilizing bacteria and rhizobia for improving growth and yield of mung bean (*Vigna radiata* L.). J Anim Plant Sci. 2011;21(3):4.
14. Rajendraprasad M, Vidyasagar B, Devi GU, Rao SK. Biological control of tomato damping off caused by *Rhizoctonia solani*. Int J Curr Microbiol Appl Sci. 2017;5(4):1426-32.
15. Rajendra Prasad S, Kamble UR, Sripathy KV, Udaya Bhaskar K, Singh DP. Seed bio-priming for biotic and abiotic stress management. In: Microbial inoculants in sustainable agricultural productivity: Vol. 1: Research perspectives. New Delhi: Springer India; 2016. p. 211-28.
16. Santner A, Calderon-Villalobos LIA, Estelle M. Plant hormones are versatile chemical regulators of plant growth. Nat Chem Biol. 2009;5(5):301-7.
17. Shete MH, Murumkar DR, Tirmali AM, Landge KB. Formulation of culture media for growth of nitrogen fixing, phosphate solubilizing and potash mobilizing

bacteria in a consortium. J Plant Dis Sci. 2019;14(1):41-6.
18. Subbiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Curr Sci. 1956;25:259-60.
19. Tarafder HK, Dey A, Dasgupta S. Co-inoculation of phosphate solubilizing bacteria and rhizobia for improving growth and yield of mung bean (*Vigna radiata* L.). Asian J Soil Sci. 2016;11(1):207-12.