Effect of Jeevamrutha Bio-fertilizer on Soil Fertility, Microbial Population, and Growth Performance of Mung Bean (Vigna radiata L.)

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Abstract:

The excessive use of chemical fertilizers has led to the deterioration of soil health and environmental quality, highlighting the need for sustainable biological alternatives. The present study evaluates the potential of Jeevamrutha, a traditional cow-based liquid organic bio-fertilizer, as an eco-friendly biological tool for sustainable agriculture. Jeevamrutha was prepared using indigenous cow dung, cow urine, jaggery, pulse flour, and rhizospheric soil, and its physical, chemical, and microbial properties were analyzed. Different concentrations of Jeevamrutha were applied to mung bean plants to assess growth parameters, biochemical attributes, and soil microbial activity. The results revealed that 75% Jeevamrutha concentration significantly enhanced fresh and dry biomass compared to the control. Microbial analysis indicated a rich population of plant growth-promoting rhizobacteria (PGPR), with notable ammonia production, indole-3-acetic acid (IAA) synthesis, and phosphate solubilization activities among several bacterial isolates. These findings demonstrate that Jeevamrutha improves soil fertility by enriching beneficial microflora and promoting plant growth, thereby reducing dependence on synthetic fertilizers. The study confirms the role of Jeevamrutha as an effective, low-cost, and farmer-friendly biological tool for sustainable environmental management and organic farming systems.

1. Introduction:

The excessive and continuous use of chemical fertilisers in modern agriculture has resulted in the deterioration of soil fertility, nutrient imbalances, environmental pollution, and a reduction in beneficial soil microbial populations. Consequently, sustainable agricultural practices emphasizing soil health restoration and ecological balance have gained significant importance in recent years. Among the various sustainable approaches, the use of organic biofertilizers has emerged as an effective strategy for maintaining soil productivity and environmental sustainability. Cow-based bioformulations are particularly important due to their higher microbial load, rapid decomposition rate, low-cost preparation, and eco-friendly nature (Anandan et al. 2016)

Jeevamrutha is a traditional Indian organic biofertilizer widely used in natural farming systems, particularly in rural agricultural practices. It is generally prepared using cow dung, cow urine, jaggery, pulse flour, soil from the rhizosphere region, and water. The formulation acts as a microbial inoculant, stimulating microbial activity in soil and thereby enhancing nutrient availability and plant growth. The microbial diversity and metabolites present in

Jeevamrutha significantly contribute to improved soil organic carbon, nutrient cycling, and plant health (Devakumar et al.2014).

In addition to Jeevamrutha, several other indigenous organic formulations such as Panchagavya, Amritpani, Sanjibani, and Kunapajala have been investigated for their role in sustainable agriculture. (S. Vijayendra et. al. 2001) However, Jeevamrutha has received considerable attention because of its simple preparation method, minimal precursor requirements, enhanced earthworm activity, and ability to improve soil microbial populations. The formulation is considered economically feasible and suitable for small and marginal farmers practicing organic agriculture (Stres et. al. 2008)

Each component of Jeevamrutha performs a specific role during fermentation and nutrient enrichment. Cow dung and cow urine serve as rich sources of beneficial microorganisms and nutrients, while jaggery and pulse flour provide carbon and nitrogen sources necessary for microbial proliferation. Soil collected from the rhizosphere acts as a microbial inoculum that enhances microbial diversity within the formulation. These interactions collectively improve soil fertility, nutrient mineralization, and plant resistance against pathogens (Sutar et al, 2019).

Several investigations have reported the positive influence of Jeevamrutha on crop growth, yield, microbial activity, and soil fertility. Application of Jeevamrutha significantly improved crop productivity in rice, capsicum, maize, chickpea, cowpea, and other crops under organic farming systems (Amareswari & Sujathamma, 2014). Studies have demonstrated that Jeevamrutha enhances plant height, biomass accumulation, nutrient uptake, and yield attributes while reducing dependence on synthetic fertilizers (Liu et. al.,2017).

Despite the increasing popularity of Jeevamrutha, several aspects related to its preparation, incubation period, nutrient composition, and seasonal variability remain insufficiently explored. Previous studies reported varying incubation periods ranging from 3 to 10 days depending on climatic conditions and geographical regions. Seasonal variations may influence microbial activity, nitrogen mineralization, and phosphorus availability in the formulation, especially under adverse environmental conditions. Furthermore, limited information is available regarding the optimization of precursor composition and nutrient responses in solid Jeevamrutha formulations (Boraiah et al. 2017).

Moreover, the phytotoxicity and germination behavior of Jeevamrutha formulations require scientific validation before large-scale agricultural applications. Germination index and seedling growth responses are important indicators for evaluating the maturity and safety of

organic biofertilizers. Hence, understanding the interaction between nutrient composition, microbial activity, and phytotoxic effects is essential for developing effective and sustainable Jeevamrutha formulations suitable for organic farming systems (Anthony et al, 2017).

The present study was therefore undertaken to evaluate the influence of Jeevamrutha on plant growth and nutrient characteristics, optimize critical formulation parameters, and assess its suitability as an eco-friendly biofertilizer for sustainable agricultural practices.

2. Materials and Methods

2.1 Preparation of Jeevamrutha

Jeevamrutha was prepared following the traditional natural farming method described by Palekar (2006) with slight modifications. The formulation consisted of fresh dung and urine collected from indigenous cows, jaggery, pulse flour, rhizospheric soil, and water. Approximately 10 kg of fresh cow dung, 10 L cow urine, 2 kg jaggery, 2 kg pulse flour (gram flour), and 1 kg soil collected from the rhizosphere region beneath a banyan tree were mixed thoroughly in 180 L of water in a plastic container. The mixture was stirred clockwise for approximately 5 min twice daily, once in the morning and once in the evening, to facilitate aeration and microbial activity. The container was covered with a clean jute cloth and kept under shaded conditions for fermentation. After 4–5 days of incubation, the Jeevamrutha formulation was considered ready for experimental application (Behera & Chandrashekara,2023). The preparation process was carried out under ambient environmental conditions to encourage the proliferation of beneficial microorganisms naturally present in cow dung, cow urine, and rhizospheric soil. The fermented liquid formulation was filtered before application to experimental plants (Vibha et al., 2020).

2.2 Physicochemical Characterization of Jeevamrutha

The prepared Jeevamrutha formulation was analyzed for various physical and chemical properties using standard analytical procedures. Colour and odour were determined through visual and sensory evaluation, respectively. The pH and electrical conductivity (EC) were measured using a digital pH meter and conductivity meter according to standard soil and plant analytical methods described by Jackson (1973). Total nitrogen content was estimated by the Micro-Kjeldahl method, whereas total phosphorus was determined following nitric–perchloric acid digestion using the vanado-molybdo phosphoric yellow colour method. Total potassium concentration was measured using flame photometry after acid digestion. Calcium and magnesium contents were estimated using Atomic Absorption Spectrophotometry (AAS).

Micronutrients including iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were also quantified using AAS following nitric–perchloric acid digestion.

Table 1. Physicochemical properties and analytical methods used for Jeevamrutha characterization

Sr. No.	Parameter	Method
1	Colour	Visual evaluation
2	Odour	Sensory evaluation
3	pH	Digital pH meter
4	Electrical conductivity	Conductivity meter
5	Total nitrogen	Micro-Kjeldahl method
6	Total phosphorus	Vanado-molybdo phosphoric yellow colour method
7	Total potassium	Flame photometry
8	Calcium	Atomic Absorption Spectrophotometry
9	Magnesium	Atomic Absorption Spectrophotometry
10	Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometry

2.3 Extraction and Estimation of Chlorophyll Content

Fresh leaves of mung bean (Vigna radiata L.) plants were used for chlorophyll extraction. Approximately 1 g of finely chopped fresh leaf tissue was homogenized in 10 mL of 80% acetone using a chilled mortar and pestle. The homogenate was centrifuged at 5000 rpm for 5 min, and the supernatant was collected for spectrophotometric analysis. Absorbance values were recorded at 645 nm and 663 nm using acetone as a blank.

Chlorophyll concentrations were calculated according to the method of Arnon (1949) using the following equations:

Total Chlorophyll: 20.2(A645) + 8.02(A663)

Chlorophyll a: 12.7(A663) – 2.69(A645)

Chlorophyll b: 22.9(A645) – 4.68(A663)

2.4 Determination of Total Protein Content

Total soluble protein content was estimated following the Bradford method. Approximately 1 g of fresh mung bean leaves was homogenized in tris buffer containing polyvinylpolypyrrolidone (PVP). The homogenized sample was centrifuged at 10,000 rpm for 20 min. Subsequently, 0.1 mL of the supernatant was mixed with 3 mL Bradford reagent and

incubated for 5 min at room temperature. Absorbance was measured at 595 nm using a UV–Visible spectrophotometer (UV-3200). Protein concentration was determined using bovine serum albumin (BSA) as the standard.

2.5 Determination of Total Carbohydrate Content

Total carbohydrate content was estimated using the anthrone method. About 100 mg of fresh mung bean leaves was homogenized in 96% ethanol and centrifuged at 3500 × g for 10 min. Subsequently, 0.5 mL of the supernatant was reacted with 3 mL freshly prepared anthrone reagent and heated in a boiling water bath for 10 min. After cooling to room temperature, absorbance was measured at 652 nm using a spectrophotometer. Glucose was used as the standard for carbohydrate quantification (Hedge & Hofreiter, 1962).

2.6 Estimation of Total Phenolic Content

Total phenolic content in mung bean leaf extracts was determined using the Folin–Ciocalteu method. Briefly, 1 mL of plant extract was mixed with 15 mL distilled water, 4 mL Folin–Ciocalteu reagent, and 6 mL of 20% sodium carbonate solution. The reaction mixture was incubated for 2 h at room temperature, and absorbance was recorded at 760 nm using a spectrophotometer. Gallic acid was used as the standard, and total phenolic content was expressed as gallic acid equivalents. (del Rosario Cappellari et al.,2013)

2.7 Detection of Indole-3-Acetic Acid (IAA) Producing Bacterial Isolates

IAA production by bacterial isolates present in Jeevamrutha was screened using the Salkowski reagent method. Bacterial cultures were grown in Luria–Bertani (LB) broth with and without tryptophan supplementation. About 2 mL of culture supernatant was mixed with 1 mL of Salkowski reagent containing 0.5 M FeCl3 in 35% perchloric acid and incubated in the dark for 30 min. The development of pink colouration indicated positive IAA production by the bacterial isolates.

2.8 Determination of Phosphate Solubilization Activity

Phosphate solubilization efficiency of bacterial isolates was qualitatively evaluated using Pikovskaya's agar medium. Bacterial cultures were streaked onto sterile agar plates and incubated at 30 + 2°C for 5 days. Formation of a clear halo zone surrounding the bacterial colony indicated phosphate solubilization activity

2.9 Determination of Ammonia Production

Ammonia production by bacterial isolates was determined using peptone water medium. Freshly grown bacterial cultures were inoculated into 10 mL peptone water and incubated at 28 ± 2°C for 48–72 h. Subsequently, 0.5 mL Nessler's reagent was added to the culture broth. Development of yellow to brown coloration indicated positive ammonia production.

3. Results and Discussion

3.1 Physicochemical Properties of Jeevamrutha

The prepared Jeevamrutha exhibited moderate green colour with a mild foul odour, indicating active microbial fermentation during the incubation period. The physicochemical analysis revealed an alkaline pH (8.24) and electrical conductivity (1.44 dS m^{-1}), suggesting the presence of dissolved mineral nutrients and microbial metabolites in the formulation (Table 2). The nutrient analysis showed appreciable concentrations of nitrogen (658 ppm), phosphorus (195 ppm), and potassium (821 ppm), indicating the potential of Jeevamrutha as a nutrient-rich organic biofertilizer.The presence of macro- and micronutrients in Jeevamrutha may be attributed to the decomposition of organic substrates and microbial mineralization processes occurring during fermentation. Similar observations were reported by Bhattacharjee and Uppaluri (2022), who demonstrated that Jeevamrutha contains diverse microbial communities capable of nutrient mobilization and soil fertility enhancement. The alkaline pH observed in the present study may facilitate nutrient availability and microbial activity in agricultural soils.

Micronutrient analysis further revealed the presence of calcium, magnesium, iron, zinc, manganese, and copper in both Jeevamrutha samples (Table 3). Jeevamrutha-01 showed comparatively higher concentrations of calcium (188.38 ppm), magnesium (1045.34 ppm), and iron (17.92 ppm) than Jeevamrutha-02, indicating variability in nutrient composition due to differences in substrate quality, fermentation conditions, and microbial activity.

Table 2. Physicochemical properties of Jeevamrutha

Parameter	Jeevamrutha
Colour	Moderate green
Odour	Mild foul smell
pH	8.24
EC (dS m^{-1})	1.44
Nitrogen (ppm)	658
Phosphorus (ppm)	195
Potassium (ppm)	821

Table 3. Micronutrient composition of Jeevamrutha samples

Sr. No.	Parameter	Jeevamrutha-01 (ppm)	Jeevamrutha-02 (ppm)
1	Calcium (Ca)	188.38	44.08

2	Magnesium (Mg)	1045.34	74.31
3	Copper (Cu)	0.10	0.32
4	Manganese (Mn)	1.60	0.28
5	Zinc (Zn)	1.30	0.05
6	Iron (Fe)	17.92	0.04

The results are in agreement with previous studies reporting that Jeevamrutha acts as a reservoir of essential nutrients and beneficial microorganisms that improve soil fertility and crop productivity (Sutar et al., 2018).

3.2 Morphological Changes in Mung Bean Plants Treated with Jeevamrutha

Visible morphological variations were observed in mung bean (Vigna radiata L.) plants treated with different concentrations of Jeevamrutha (Figure 1). Plants receiving Jeevamrutha treatments showed enhanced vegetative growth compared to the control group. Among all treatments, 75% and 100% Jeevamrutha concentrations exhibited comparatively vigorous growth, increased leaf development, and improved plant appearance.

The improved growth performance may be associated with enhanced nutrient availability and increased microbial activity stimulated by Jeevamrutha application. Beneficial microorganisms present in the formulation may enhance nutrient uptake, phytohormone production, and root proliferation, ultimately promoting plant growth.

3.2.1 Morphological changes on Mung plant

Root and shoot length measurements showed significant variation among Jeevamrutha treatments during the experimental period (Table 4). At 10 days after treatment, the highest root length (8.2 cm) was observed in plants treated with 100% Jeevamrutha, whereas the control plants showed the lowest root length (4.3 cm). Similar trends were observed during subsequent growth stages.

Similarly, shoot length increased substantially with Jeevamrutha treatment. Maximum shoot growth (25.5 cm) was recorded in the 100% Jeevamrutha treatment after 30 days, whereas control plants exhibited comparatively lower growth (16 cm). Enhanced root and shoot development may be attributed to increased nutrient mobilization, microbial activity, and production of growth-promoting substances such as indole-3-acetic acid (IAA) by rhizospheric microorganisms present in Jeevamrutha. Similar observations were reported by Kloepper et al. (1980), who demonstrated that plant growth-promoting rhizobacteria (PGPR) enhance root development and overall plant biomass.

Table 4. Effect of Jeevamrutha on Root and Shoot Length of *Vigna radiata* under Different Treatments

Treatment	Root Length (cm) 10 DAS	Root Length (cm) 20 DAS	Root Length (cm) 30 DAS	Shoot Length (cm) 10 DAS	Shoot Length (cm) 20 DAS	Shoot Length (cm) 30 DAS
Control	4.3	5.3	3.8	11.5	17.0	16.0
25% Jeevamrutha	7.0	5.5	4.0	13.3	21.0	18.5
50% Jeevamrutha	4.6	5.4	5.5	14.9	17.5	21.1
75% Jeevamrutha	7.3	5.0	3.9	12.2	16.5	22.5
100% Jeevamrutha	8.2	7.4	4.1	9.5	22.0	25.5

DAS = Days After Sowing

Root and shoot growth of mung bean plants improved under Jeevamrutha treatments compared with the control (Figure 2). The maximum root length at 10 and 20 DAS was observed under 100% Jeevamrutha treatment (8.2 cm and 7.4 cm, respectively), while the highest root length at 30 DAS was recorded under 50% Jeevamrutha treatment (5.5 cm). Shoot length increased progressively with treatment concentration, and the highest shoot length at 30 DAS was observed under 100% Jeevamrutha treatment (25.5 cm).

Fig: 1 Morphological change of plant under the different concentration of Jeevamrutha

Fresh and dry biomass accumulation increased significantly in Jeevamrutha-treated plants compared to control plants. Among all treatments, the 75% Jeevamrutha concentration exhibited the highest dry weight (0.1500 g) after 30 days, while the highest fresh weight (0.6919 g) was also recorded under the same treatment.

The increase in plant biomass suggests improved photosynthetic efficiency and nutrient assimilation in Jeevamrutha-treated plants. The findings corroborate earlier reports indicating that organic biofertilizers improve plant metabolic activity and biomass accumulation.

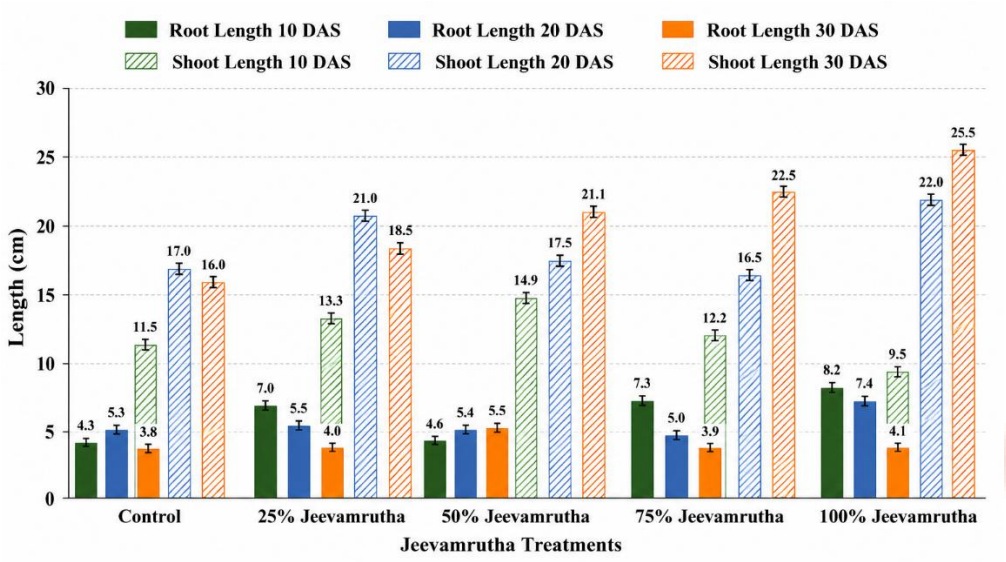


Figure 2. Effect of different concentrations of *Jeevamrutha* on root and shoot length of *Vigna radiata*. Root length (solid bars) and shoot length (hatched bars) were recorded at 10, 20, and 30 days after sowing (DAS). Plants treated with 100% *Jeevamrutha* showed the highest root length (7.4 cm) and shoot length (25.5 cm) at 20 and 30 DAS, respectively. Values are means ± SD (n = 3).
DAS = Days After Sowing

3.2.2 Biomass Accumulation of Mung Plant

Biomass accumulation was enhanced in Jeevamrutha-treated plants compared with the control (Figure 3). The highest dry weight at 30 DAS was observed under 75% Jeevamrutha treatment (0.1500 g), whereas the highest fresh weight at 30 DAS was also recorded under 75% Jeevamrutha treatment (0.6919 g). These findings indicate improved biomass production and physiological performance in plants receiving Jeevamrutha application. (Table 5)

Table 5. Effect of Jeevamrutha on Dry Weight and Fresh Weight of *Vigna radiata* under Different Treatments

Treatment	Dry Weight (g) 10 DAS	Dry Weight (g) 20 DAS	Dry Weight (g) 30 DAS	Fresh Weight (g) 10 DAS	Fresh Weight (g) 20 DAS	Fresh Weight (g) 30 DAS
Control	0.0471	0.0509	0.0439	0.2851	0.2774	0.2370

25% Jeevamrutha	0.0668	0.0828	0.1065	0.5330	0.4602	0.4819
50% Jeevamrutha	0.0659	0.0586	0.1204	0.5901	0.3507	0.5377
75% Jeevamrutha	0.0599	0.0595	0.1500	0.5135	0.2830	0.6919
100% Jeevamrutha	0.0483	0.0755	0.1025	0.3509	0.4015	0.4803

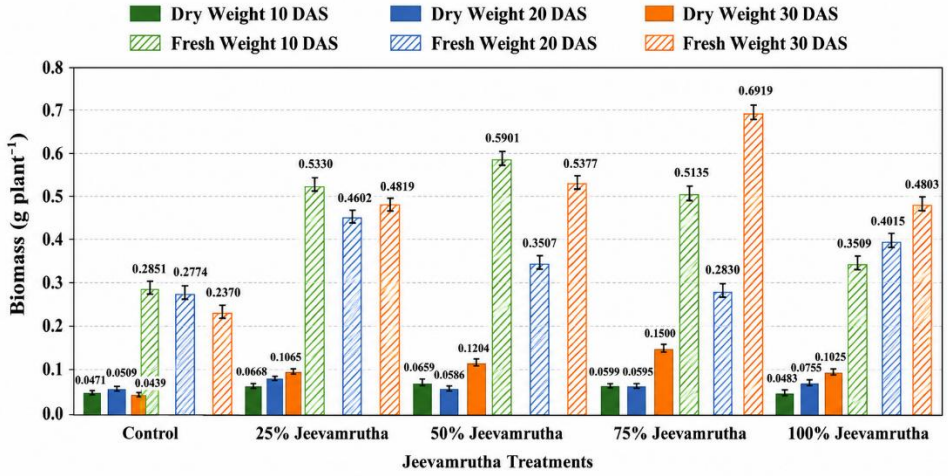


Figure 3. Effect of different concentrations of *Jeevamrutha* on biomass accumulation of *Vigna radiata*. Dry weight (solid bars) and fresh weight (hatched bars) were recorded at 10, 20, and 30 days after sowing (DAS). Plants treated with 75% *Jeevamrutha* exhibited the highest fresh weight (0.6919 g plant^{-1}) and dry weight (0.1500 g plant^{-1}) at 30 DAS. Values are means ± SD (n = 3).

3.3 Biochemical estimation after the treatment of Jeevamrutha on Mung Bean Plant

3.3.1 Chlorophyll Content

Chlorophyll content varied among the Jeevamrutha treatments throughout the experimental period. At 10 DAS, the highest chlorophyll content was recorded in the 50% Jeevamrutha treatment (489.93), which was approximately 2.7-fold higher than the control (181.24). At 20 DAS, the maximum chlorophyll content was observed in the 25% Jeevamrutha treatment (570.59), representing a 40.1% increase over the control (407.17). At 30 DAS, the highest chlorophyll content was recorded in the 100% Jeevamrutha treatment (448.08), which was 25.7% higher than the control (356.48). These findings indicate that Jeevamrutha enhanced photosynthetic pigment synthesis and improved the physiological performance of mung bean plants. (Figure 4)

Table 6. Effect of Jeevamrutha on Biochemical Parameters of *Vigna radiata* under Different Treatments

Treatment	Chlorophyll 10 DAS	Chlorophyll 20 DAS	Chlorophyll 30 DAS	Protein 10 DAS	Protein 20 DAS	Protein 30 DAS	Carbohydrate 10 DAS	Carbohydrate 20 DAS	Carbohydrate 30 DAS	Phenol 10 DAS	Phenol 20 DAS	Phenol 30 DAS
Control	181.243	407.1677	356.4817	0.3980	0.0004	1.1694	0.7000	3.4577	0.1773	0.6800	0.0859	0.0429

25% Jeevamrutha	325.1195	570.5913	367.7355	0.5940	0.0936	1.3962	0.9690	2.1398	0.2052	0.6980	0.0927	0.0580
50% Jeevamrutha	489.9331	336.6772	423.9042	0.7070	0.0816	1.5617	1.1060	2.3425	0.0718	0.8250	0.0868	0.0485
75% Jeevamrutha	422.7953	354.5711	439.0381	0.5290	0.1338	1.5532	0.8990	3.4227	0.2167	0.8570	0.0776	0.0589
100% Jeevamrutha	297.3324	351.7065	448.0794	0.3860	0.0644	1.5354	0.7730	3.8415	0.2702	0.5210	0.0729	0.0499

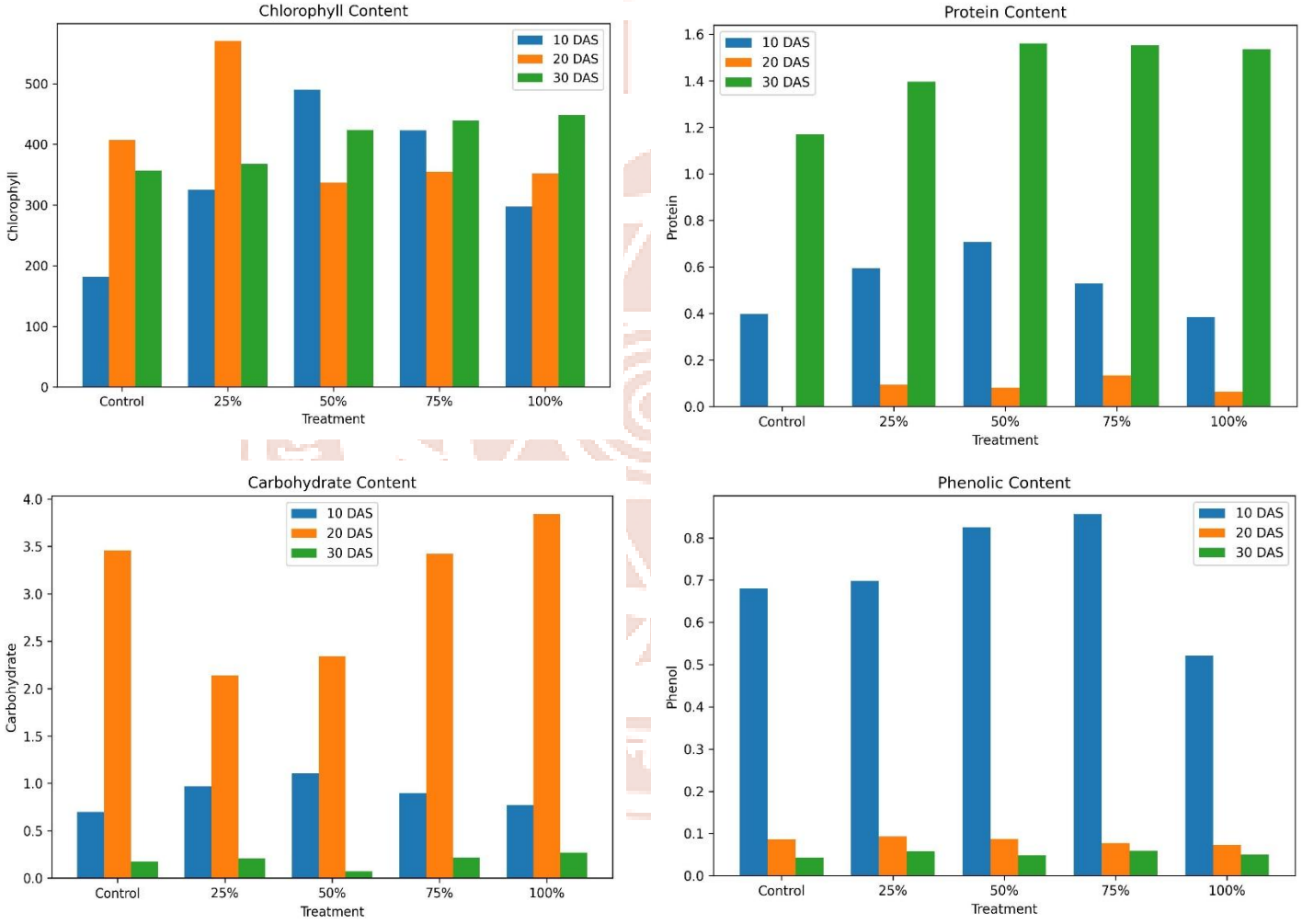


Fig 4: Effect of Jeevamrutha on Biochemical Parameters of *Vigna radiata* under Different Treatments

3.3.2 Protein Content

Protein content increased in all Jeevamrutha-treated plants compared with the control. At 10 DAS, the highest protein content was observed in the 50% Jeevamrutha treatment (0.707), representing a 77.6% increase over the control (0.398). At 30 DAS, the maximum protein

content was again recorded in the 50% Jeevamrutha treatment (1.5617), which was approximately 33.5% higher than the control (1.1694). The increased protein accumulation suggests enhanced nitrogen assimilation and metabolic activity under Jeevamrutha application.

3.3.3 Carbohydrate Content

Carbohydrate content was positively influenced by Jeevamrutha treatment. At 10 DAS, the highest carbohydrate content was observed under the 50% Jeevamrutha treatment (1.106), a 58.0% increase over the control (0.700). At 20 DAS, the highest value was recorded under 100% Jeevamrutha treatment (3.8415), 11.1% higher than the control (3.4577). At 30 DAS, 100% Jeevamrutha treatment again exhibited the maximum carbohydrate content (0.2702), representing a 52.5% increase over the control (0.1773). Enhanced carbohydrate accumulation reflects improved photosynthetic activity and assimilate production.

3.3.4 Phenolic Content

Phenolic content showed a positive response to Jeevamrutha application. At 10 DAS, the highest phenolic content was recorded under 75% Jeevamrutha treatment (0.857), which was 26.0% higher than the control (0.680). At 30 DAS, the same treatment exhibited the highest phenolic content (0.0589), representing a 37.3% increase over the control (0.0429). Increased phenolic accumulation indicates improved antioxidant capacity and activation of plant defense mechanisms. The biochemical analysis revealed that Jeevamrutha substantially improved physiological and metabolic attributes of Vigna radiata. Among the tested concentrations, 50–100% Jeevamrutha treatments generally produced the highest chlorophyll, protein, and carbohydrate contents, while 75% Jeevamrutha resulted in the greatest phenolic accumulation. Compared with the control, chlorophyll increased by up to 169.8%, protein by 77.6%, carbohydrate by 58.0%, and phenolic content by 37.3% at different growth stages. (Table 6) These results demonstrate that Jeevamrutha enhances photosynthetic efficiency, nutrient assimilation, metabolic activity, and plant defense responses, thereby contributing to improved growth and vigor of mung bean plants.

3.4 Plant Growth-Promoting Rhizobacterial (PGPR) Activities

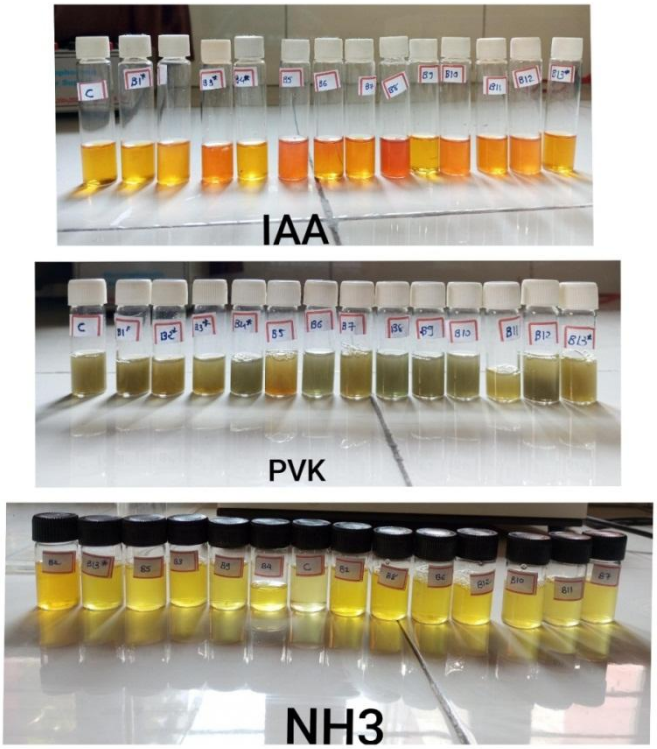
Thirteen bacterial isolates obtained from Jeevamrutha exhibited various PGPR activities including ammonia production, indole-3-acetic acid (IAA) production, and phosphate solubilization (Table 7).

Table 7. PGPR activities of bacterial isolates obtained from Jeevamrutha

Isolate	NH_3	IAA	PVK
B1	+	–	+

B2	+	–	–
B3	+	+	+
B4	+	–	–
B5	+	+	–
B6	+	–	+
B7	+	–	+
B8	+	+	–
B9	+	–	–
B10	+	+	+
B11	+	+	–
B12	+	+	–
B13	+	–	+

All bacterial isolates showed positive ammonia production, whereas IAA production was observed in isolates B3, B5, B8, B10, B11, and B12. Phosphate solubilization activity was detected in isolates B1, B3, B6, B7, B10, and B13. (Figure 5)



The presence of PGPR in Jeevamrutha indicates its strong microbial potential for enhancing soil fertility and plant growth. PGPR microorganisms are known to improve nutrient

solubilization, phytohormone production, and root development. Similar findings were reported by Das and Singh (2014), who observed enhanced soil nutrient status and microbial activity following PGPR application.

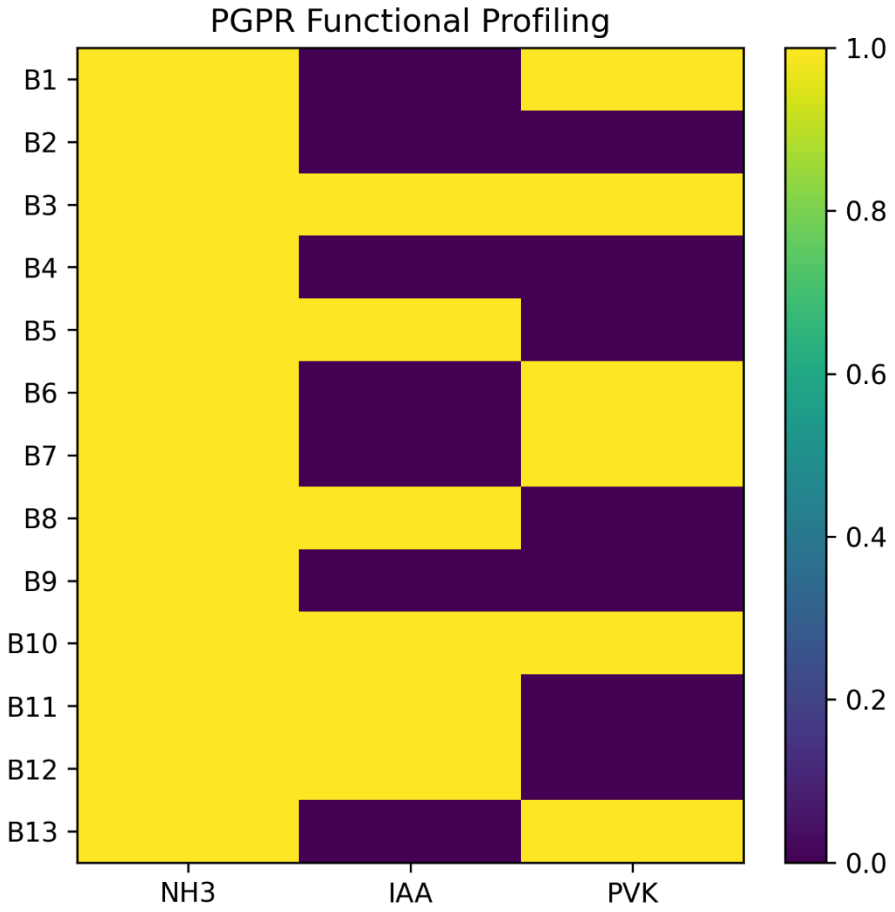


Fig 5: PGPR Functional Profiling

4. Discussion

The present study demonstrated that Jeevamrutha significantly improved the growth and physiological performance of mung bean (Vigna radiata L.) plants. The enhancement in plant growth may be attributed to the nutrient-rich composition and beneficial microbial population present in the fermented formulation. Jeevamrutha contained appreciable amounts of nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients, which are essential for plant metabolism, chlorophyll synthesis, and cellular development. Similar observations were reported by Bhattacharjee and Uppaluri (2022), who suggested that fermentation during Jeevamrutha preparation enhances nutrient availability and microbial activity.

Application of Jeevamrutha positively influenced root and shoot growth, fresh weight, and dry biomass of mung bean plants. Higher growth responses observed under 75% and 100%

Jeevamrutha treatments may be associated with improved nutrient uptake and microbial stimulation in the rhizosphere region. Plant growth-promoting rhizobacteria (PGPR) present in Jeevamrutha are known to enhance root elongation, nutrient absorption, and overall plant vigor through phytohormone production and nutrient mobilization (Kloepper et al., 1980).

The increase in chlorophyll content observed in treated plants indicates improved photosynthetic efficiency under Jeevamrutha application. Nitrogen present in the formulation likely contributed to enhanced chlorophyll biosynthesis, resulting in greater biomass accumulation. Similarly, increased protein and carbohydrate contents in treated plants suggest improved nitrogen metabolism, photosynthesis, and energy storage. Enhanced phenolic content further indicates activation of antioxidant and defense mechanisms in response to Jeevamrutha treatment (Manjunatha et al,2022).

The bacterial isolates obtained from Jeevamrutha exhibited important PGPR traits such as ammonia production, phosphate solubilization, and indole-3-acetic acid (IAA) production. These microbial activities may contribute to improved nutrient availability and root development, thereby promoting plant growth. Das and Singh (2014) also reported that organic manures integrated with PGPR improve soil fertility and nutrient status. Jeevamrutha acts as an effective and eco-friendly organic biofertilizer capable of improving plant growth, biochemical characteristics, and microbial activity. Its application may reduce dependence on chemical fertilizers and support sustainable agricultural practices.

5. Conclusion

The present study demonstrated that Jeevamrutha is an effective organic biofertilizer capable of enhancing the growth, biochemical characteristics, and microbial activity associated with mung bean cultivation. The formulation contained appreciable levels of essential macro- and micronutrients that contributed to improved plant growth and metabolic performance. Among the tested concentrations, 75% Jeevamrutha was found to be the most effective treatment for biomass accumulation and phenolic enhancement, whereas 100% Jeevamrutha promoted maximum shoot growth. Jeevamrutha-treated plants exhibited enhanced root and shoot growth, biomass accumulation, chlorophyll content, protein content, carbohydrate content, and phenolic content compared with control plants. The study also confirmed the presence of beneficial plant growth-promoting rhizobacteria exhibiting ammonia production, phosphate solubilization, and IAA production. These microbial activities likely contributed to improved nutrient availability and plant growth promotion. The findings highlight the potential

of Jeevamrutha as a low-cost, eco-friendly, and sustainable alternative to chemical fertilizers for improving crop productivity and soil health.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Author Contributions

RP: Conceptualization, supervision, data interpretation, manuscript review, and correspondence. **KP:** Guidance, methodology development, manuscript review, and technical support.

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