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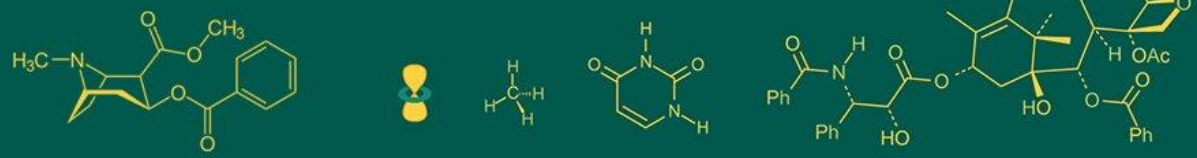

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Role of pink pigmented facultative methylotrophic bacteria in promoting growth and yield of greengram (*Vigna radiata* L.)

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Abstract
The present experiment, entitled "Role of pink pigmented facultative methylotrophic bacteria in promoting growth and yield of Greengram (*Vigna radiata* L.)" was carried out during *Rabi* season 2023-24 at the College Farm, College of Agriculture, Rajendranagar, to evaluate the influence of methylotrophic bacteria on the growth and yield of greengram. The study consists of nine treatments arranged in a randomised block design with three replications**.** Results revealed that seed treatment or foliar application of methylotrophic bacteria did not significantly affect plant height. However, dry matter production and yield components such as number of pods per plant and grains per pod were markedly improved. Among the different treatments, seed treatment combined with foliar spray of 2% PPFM (Pink Pigmented Facultative Methylotrophic bacteria) at flowering and pod formation recorded the highest grain yield (1358 kg ha^{-1}) and haulm yield (2420 kg ha^{-1}). This treatment was statistically on par with seed treatment using 1% PPFM plus foliar application of 1% PPFM at flowering and pod formation, which produced grain and haulm yields of 1282 kg ha^{-1} and 2245 kg ha^{-1}, respectively. The combined application of 2% PPFM also resulted in maximum gross returns (₹115,430 ha^{-1}) and net returns (₹77,814 ha^{-1}). In contrast, the highest benefit-cost ratio (2.34) was obtained with seed treatment and foliar spray of 1% PPFM.

Keywords: Greengram, PPFM, foliar spray, seed treatment, yield and economics

Introduction
The rapid increase in global population has intensified the demand for food, leading to the indiscriminate use of chemical fertilizers. While these inputs initially boost crop productivity, their overuse has resulted in soil degradation and environmental concerns. Hence, sustainable strategies that enhance yield without compromising soil health are urgently needed. Bioinoculants, which are microbial formulations containing single or consortia of beneficial microorganisms, have gained importance as eco-friendly alternatives to chemical fertilizers. They promote plant growth, improve nutrient availability, and help in reducing environmental impacts.

Among bioinoculants, methylotrophic bacteria—particularly Pink Pigmented Facultative Methylotrophs (PPFM)—have shown promise in sustainable agriculture. These bacteria colonize both rhizosphere and phyllosphere, where they enhance plant growth by producing phytohormones such as cytokinins and auxins, solubilizing phosphorus, producing siderophores, and inducing resistance against pathogens (Mandhiyan *et al.*, 2004) [5]. Different studies have reported that PPFM application, either as seed inoculants or foliar sprays, improves soil microbial activity, nutrient availability, seed germination, and crop yields (Jeya Jyothi *et al.*, 2014; Raghavendra *et al.*, 2019) [1, 10]. Considering these advantages, the present study was conducted to evaluate the effect of PPFM on the growth and yield of greengram, hypothesising that seed treatment coupled with foliar application would positively influence crop performance.

Material and Methods
A field experiment entitled "Role of pink pigmented facultative methylotrophic bacteria in promoting growth and yield of Greengram (*Vigna radiata* L.)" was conducted during *Rabi* 2023-24 at the College Farm, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad,

to evaluate the effect of PPFM on greengram (var. WGG-42). The experiment was designed with nine treatments and three replications in a simple randomized block design. Treatments included seed treatment with *Rhizobium* (T_1), seed treatment with 1% PPFM (T_2), Seed treatment with 2% PPFM (T_3) seed imbibition with water (T_4), Foliar spray of 1% PPFM at flower initiation and pod formation stages (T_5), foliar spray of 2% PPFM at flowering and pod formation (T_6), Seed treatment with 1% PPFM + Foliar spray of 1% PPFM at flower initiation and pod formation stages(T_7), Seed treatment with 1% PPFM + Foliar spray of 2% PPFM at flower initiation and pod formation stages (T_8), and Water spraying at flower initiation and pod formation stages (T_9)- The experimental field was neutral in condition (pH 7.1), low in nitrogen content (233.7 kg ha^{-1}), high in phosphorus content (32.7 kg ha^{-1}), and medium in potassium content (334.2 kg ha^{-1}). The experimental crop was sown on 25th October 2023 with 30 × 10 cm spacing apart. Pendimethalin was applied as a pre-emergence herbicide within 24 h of sowing, and a uniform basal dose of fertilizers was applied for all the treatments. PPFM inoculation and foliar sprays were imposed as per treatments. The crop was harvested on 17th January 2024. The biometric observations were recorded by selecting five plants randomly per treatment, and treatment means were used for analysis.

Results and Discussion

Growth and Yield of green gram

The different treatment combinations like seed treatment, seed imbibition, and foliar spray did not significantly influence plant height; however, dry matter production varied markedly. Seed treatment with 1% PPFM combined with foliar spray of 2% PPFM at flowering and pod formation stages recorded the highest dry matter accumulation, statistically on par with seed treatment with 1% PPFM and foliar spray of 1% PPFM at the same stages. The enhanced dry matter production can be attributed to the ability of methylotrophic bacteria to promote seed germination and seedling growth through synthesising phytohormones such as cytokinins and auxins (Long, 2000) [3] and their role in atmospheric nitrogen fixation. The lowest dry matter production was observed in the seed imbibition with water treatment, corroborating the earlier findings of Mandhiyan *et al.* (2004) [5].

Foliar application of 2% PPFM at flowering and pod formation and seed treatment also resulted in a significant increase in yield attributes, grain yield, and haulm yield. This treatment was on par with seed treatment with 1% PPFM and foliar spray of 1% PPFM at the same growth stages. The improvement may be due to enhanced nutrient availability and uptake. Similar positive effects of methylotrophs on germination, plant growth, and yield have been reported in barnyard millet (Poorniammal *et al.*, 2020) [9], while Mandhiyan *et al.* (2004) [5] and Om base *et al.* (2003) [7] also documented increased seedling vigour, dry matter accumulation, and yield with PPFM inoculation.

Correlation among yield attributes and yield

Correlation analysis was carried out between the different parameters like plant height, number pods per plant, number of seeds per pod, 100 seed weight, plant drymatter and grain yield to determine the relationship among the various parameters studied (Fig.1). The results shows that all the parameters are positively correlated with grain yield and Haulm yield. A significant correlation (p<0.05) was also observed between between grain yield and plant dry matter, pod per plant, seeds per pod. The results are in conformity with Narayanan Vijayanand *et al.*, 2021 [8].

Economics

Cost of cultivation: The maximum cost of cultivation was observed with treatment of seed treatment and foliar spray of 2% PPFM (₹37,616 ha^{-1}), followed by seed treatment and foliar spray of 1% PPFM (₹37,316 ha^{-1}). The lowest cost was recorded with seed imbibition with water (₹26,866 ha^{-1}).

Gross returns: Gross returns of different treatments varied across, with the highest being recorded in seed treatment + foliar spray of 2% PPFM (₹115,430 ha^{-1}), followed by seed treatment + foliar spray of 1% PPFM (₹94,055 ha^{-1}). The lowest gross return was noted in seed imbibition with water (₹43,945 ha^{-1}). These results are in tune with the findings of Vigneshwarraj *et al.* (2020) [12].

Net returns: Seed treatment with 1% PPFM + foliar spray of 2% PPFM contributed the maximum net returns (₹77,814 ha^{-1}), closely followed by seed treatment + foliar spray of 1% PPFM (₹76,363 ha^{-1}). The operations of seed treatments and other special practices helped reduce the cost of cultivation, which confirms with Narendar *et al.*, 2023 [6].

Benefit-Cost (B:C) ratio: The highest B:C ratio was obtained with seed treatment + foliar spray of 1% PPFM (2.34), followed by foliar spray of 2% PPFM (2.32) and seed treatment with 2% PPFM (2.07). The lowest B:C ratio (1.64) was recorded in seed imbibition with water, supporting the earlier results of Sekar *et al.* (2010) [11].

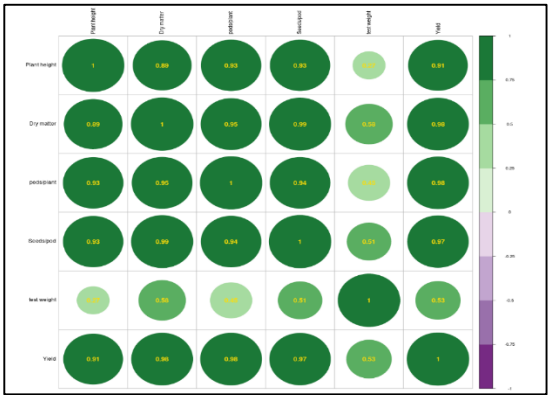

Fig 1: Effect of correlation on the greengram yield and yield attributes.

Table 1: Effect of pink-pigmented facultative methyl bacterium on growth and yield of greengram

Treatments	Plant height (cm)	Dry matter (kg ha^{-1})	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1-Seed treatment with Rhizobium	25.7	2478	889	1589
T_2-Seed treatment with 1% PPFM	25.3	2650	925	1798
T_3-Seed treatment with 2% PPFM	25.9	2871	1070	1851
T_4-Seed imbibition with water	24.9	2367	833	1533
T_5-Foliar spray of 1% PPFM at flower initiation and pod formation stages	28.9	2953	1093	1893
T_6-Foliar spray of 2% PPFM at flower initiation and pod formation stages	29.0	2975	1107	1937
T_7-Seed treatment with 1% PPFM + Foliar spray of 1% PPFM at flower initiation and pod formation stages	29.2	3528	1282	2245
T_8-Seed treatment with 1% PPFM + Foliar spray of 2% PPFM at flower initiation and pod formation stages	30.3	3779	1358	2420
T_9-Water spraying at flower initiation and pod formation stages	25.4	2632	853	1625
SE.m ±	2.00	305	115	193
CD	NS	914	344	580

Table 2: Effect of pink-pigmented facultative methyl bacterium on grain yield and economics of greengram

Treatments	Grain yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C Ratio
T_1-Seed treatment with Rhizobium	889	27016	75568	48552	1.80
T_2-Seed treatment with 1% PPFM	925	27116	78617	51501	1.90
T_3-Seed treatment with 2% PPFM	1070	27366	90973	63607	2.32
T_4-Seed imbibition with water	833	26866	70811	43945	1.64
T_5-Foliar spray of 1% PPFM at flower initiation and pod formation stages	1093	32366	92919	60553	1.87
T_6-Foliar spray of 2% PPFM at flower initiation and pod formation stages	1107	37366	94055	56689	1.52
T_7-Seed treatment with 1% PPFM + Foliar spray of 1% PPFM at flower initiation and pod formation stages	1282	32616	108979	76363	2.34
T_8-Seed treatment with 1% PPFM + Foliar spray of 2% PPFM at flower initiation and pod formation stages	1358	37616	115430	77814	2.07
T_9-Water spraying at flower initiation and pod formation stages	853	27366	72505	45139	1.65
SE.m ±	115		9765	7328	--
CD	344		29276	21971	--

Conclusion

The present investigation indicated that the number of pods, and seeds per plant significantly impacted the grain yield and Haulm yield of greengram. The highest grain yield was observed with Seed treatment with 1% PPFM and 2%foliar spray of PPFM at critical stages however, the seed treatment followed by foliar spray with 1% PPFM recorded second-best yield at par. Foliar spray of PPFM two times also gave a good yield at par with the highest grain yield treatments. The treatment of PPFM 1% seed treatment and 1% foliar spray at critical stages recorded the highest benefit-cost ratio.

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