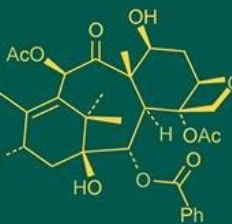
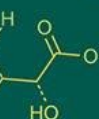
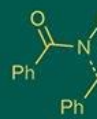


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Effect of bioinoculants on growth promoting attributes and yield of chickpea

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Abstract

The present study aimed to investigate the effect of different bioinoculants of plant growth promoting rhizobacteria on growth and yield of chickpea. The field experiment was conducted during rabi season of 2023-24 at Pulses Research Unit, Dr PDKV, Akola. The results of the study revealed that among the different treatments, seed inoculation with *Mesorhizobium* (AKCR-1) + *Pseudomonas fluorescence* + PSB + KSB + 100% RDF recorded maximum nodulation (28.33 nodules plant⁻¹), nodule dry weight (87.31 mg/ plant), root length (18.57 cm), shoot length (22.86 cm) and highest grain yield (23.6 q/ha) which was found statistically at par with the treatment of *Mesorhizobium* + *Pseudomonas fluorescence* + PSB + KSB + 75% RDF. These findings underscore the practical benefits of seed treatment with different bioinoculants for saving the chemical fertilizers.

Keywords: Bioinoculants, *Mesorhizobium*, phosphate and potassium solubilizing bacteria, *Pseudomonas*, chickpea

1. Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop all over the world covering Asia, Africa, Europe, Australia, and North America and South America continents. India's chickpea production during 2021-22 was 13.75 million tonnes from an acreage of 10.91 million ha, with a productivity of 12.6 q/ha (DES 2023, MOAF&W, GoI) ^[1, 3]. In India, chickpea has highest area in Maharashtra, Madhya Pradesh and Rajasthan. It contains 21 percent protein, 61.5 percent carbohydrates, 4.5 percent fat and is also rich in calcium, iron and niacin. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility.

Enhancing the production while keeping the environment safe is one of the major challenges in the 21st century (Berg, 2009) ^[2]. The seed inoculation with various microbial isolates significantly increased the available nutrient status and grain yield in legumes (Kamble *et al.*, 2023) ^[5]. Promoting sustainable farming practices and reducing dependence on chemical fertilizers as they are costly, deplete soil health and disrupt nutrient balance require a thorough understanding about Plant Growth-Promoting Rhizobacteria (PGPR) that can biologically fix nitrogen, solubilize phosphorus, and produce substances such as organic acids and indole acetic acid, which contribute to improved chickpea growth. PGPR are heterogeneous group of bacteria that are found in the rhizosphere, at root surfaces and in association with roots, which improve the extent or quality of plant growth directly or indirectly. These microorganisms play an important role in increasing the availability of N, P and K. Chickpea is capable of fixing atmospheric nitrogen with the help of *Rhizobium* residing in the root nodules.

Rhizobium enhances the biological nitrogen fixation of the plant which not only improves the nitrogen nutrition of inoculated chickpea but also reduces the dependence on inorganic nitrogen fertilizers (Namvar *et al.*, 2011) ^[9]. Phosphorus is an essential macronutrient crucial for the growth and development of plants. Phosphorus requirement of legume crops is higher due to higher energy consumption during the process of symbiotic nitrogen fixation (Schulze *et al.*, 2006) ^[12]. Phosphate solubilizing microorganisms (PSM) have ability to dissolve insoluble inorganic phosphorus and make them available to plants by various mechanisms

such as production of organic acids and phosphatase enzymes (Shaikh *et al.*, 2016) [13]. *Pseudomonas* promotes plant growth by mechanisms such as production of plant growth regulators and vitamins, enhancement of plant nutrient uptake and suppression of pathogenic or deleterious organisms (Glick, 1995) [4]. Potassium is essential for maintaining the ionic environment required for metabolic processes in the cytosol. It is essential for protein synthesis. Potassium solubilizing bacteria solubilize K bearing minerals and increase its availability due to the production of some weak organic acids such as citric, tartaric, etc. which causes increase in plant growth and yield (Maurya *et al.*, 2014) [8]. The preparations containing living or latent cells of efficient strains of microorganisms called biofertilizers.

Seed or soil treatment of biofertilizers help in enhancing biological nitrogen fixation through nodule formation, phosphorus solubilisation, production of phytohormones like cytokinins, gibberellins and indole acetic acid (IAA) (Verma *et al.*, 2013) [19] and also show antagonism against phytopathogens by production of siderophores, celluloses and antibiotics in chickpea (Kaur and Sharma, 2013) [6].

Biofertilizers, when applied as a consortium significantly enhance plant growth and help for maintaining soil fertility (Woo and Olimpia, 2018) [22]. Considering this, the present investigation was conducted to evaluate the effect of *Mesorhizobium* (AKCR-1), *Pseudomonas fluorescense*, Phosphate solubilizing bacteria (PSB), and Potassium solubilizing bacteria (KSB) on growth and yield of chickpea.

2. Material and Methods

The field experiment was conducted during rabi 2023-24 at Pulses Research Unit, Dr PDKV, Akola. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments including control and three replications. Chickpea seeds were inoculated as per the treatment with *Mesorhizobium* (AKCR-1), *Pseudomonas fluorescense*, PSB and KSB prior to sowing using 25 g/kg of seed. Treatment wise dose of N, P₂O₅ and K₂O was applied at the time of sowing. Each treatment has gross plot size 3.00×2.40 m² and net plot size 2.80 × 1.80 m² and replicated thrice with JAKI-9218 chickpea variety. The treatment consisted with different bioinoculants and four levels of recommended dose of fertilizers (RDF).

The data on root length, shoot length, plant height, plant dry

weight and nodulation was recorded at 45 DAS from five randomly selected plants from each plot. Seed yield was also recorded after harvesting the chickpea crop.

Data collected on various parameters of crop were subjected to statistical analysis by following the method of analysis of variance (ANOVA) given by Panse and Sukhatme (2000) [10] to draw valid conclusion.

3. Results and Discussion

3.1 Root and shoot length

The root length were recorded in the range from 8.48 to 18.57 cm at 45 DAS. The highest root length of chickpea was recorded in the combined treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF i.e. 18.57 cm, which was statistically at par with the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF i.e. 17.14 cm and significantly higher than all other treatments.

Seed treatment with *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF recorded highest shoot length i.e. 22.86 cm followed by the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF i.e. 21.35 cm. The minimum shoot length was recorded in control. The data pertaining to root and shoot length is presented in Table 1.

The results are in agreement with the findings of Vishwas *et al.*, (2017) [21], who demonstrated that seed biopriming with *Rhizobium* and *Pseudomonas* at 10% for 12 hours significantly improved germination (87%), speed of germination (77.11), shoot length (20.33 cm), root length (16.14 cm), seedling length (24.91 cm) compared to control and *Rhizobium* alone @ 10% for 12 hours.

3.2 Plant height

Difference in plant height due to different treatments was found statistically significant. Highest plant height was recorded in the combined application of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF (32.11 cm) followed by the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF (30.94 cm). Lowest plant height was recorded in control treatment (21.10 cm). These results are in agreement with the observations made by Rinku *et al.*, (2020) [11] who observed that plant height was highest in the combined application of *Rhizobium* + PSB + 100% RDF, which was closely followed by *Rhizobium* + PSB + 75% RDF.

Table 1: Effect of different bioinoculants on root length, shoot length and plant height

Treatment details	Root length (cm)	Shoot length (cm)	Plant height (cm)
Uninoculated control (T ₁)	8.48	14.37	21.10
<i>Mesorhizobium</i> (AKCR-1) (T ₂)	10.22	15.84	22.91
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> (T ₃)	11.94	17.42	24.27
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> + PSB (T ₄)	12.77	18.03	25.39
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> + PSB + KSB (T ₅)	13.03	18.74	26.73
T ₅ + 100% RDF (T ₆)	18.57	22.86	32.11
T ₅ + 75% RDF (T ₇)	17.14	21.35	30.94
T ₅ + 50% RDF (T ₈)	15.08	19.93	29.18
T ₅ + 25% RDF (T ₉)	14.87	19.56	27.62
F- test	Sig.	Sig.	Sig.
SE(m)±	0.53	0.41	0.37
CD @ 5%	1.59	1.24	1.11

3.3 Active nodules number and nodule dry weight per plant
Maximum active number of nodules (28.33 plant⁻¹) at 45 days after sowing were observed in *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF (28.33) which was statistically at par with the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF (28.20 plant⁻¹). The data regarding nodulation and nodule dry weight is represented graphically which is depicted in Fig 1.



Uninoculated control Bioinoculants with 100% RDF
Plate 1: Effect of bioinoculants on nodulation of chickpea

3.4 Plant dry weight
The data on plant dry weight as affected by different treatments is presented in Table 2. The maximum plant dry weight was recorded in the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF (5.23 g/plant), which was followed by *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF (4.98 g/plant), while minimum dry weight was found in control (3.18 g/plant). Similarly, Bansal R.K. (2009) [1] and Singh *et al.*, (2015) [16] reported that presowing inoculation of pulses seeds with different inoculants (*Rhizobium*, PGPR, and PSB), either individually or in combination, significantly increased plant height, root length, dry matter production, nodule number per plant, nutrient uptake, and seed yield compared to the uninoculated control.

3.5 Grain yield
The yield study revealed that among all the treatments,

The combined application of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF (87.31 mg/plant) recorded maximum nodule dry weight followed by *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF (85.02 mg/plant) and found superior to remaining all other treatments. The similar finding was reported by Tagore *et al.*, (2013) [17], who observed that the combination of *Rhizobium* and PSB was the most effective treatment, resulting in the increased nodule number, nodule fresh weight, nodule dry weight, shoot dry weight and grain yield.

combined application of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 100% RDF recorded highest yield (23.6 q/ha), which was statistically at par with the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF (22.31 q/ha). Singh *et al.*, (2004) [14] reported increment in the average growth and yield of green gram as influenced by bio-fertilizer and phosphorus application. Similar results was reported by Verma *et al.*, (2019) [20] and Singh *et al.*, (2018) [15], who recorded the improved yield attributes of chickpea with integration of synthetic fertilizers and biofertilizers. The present study is in agreement with Tejasree *et al.*, (2024) [18] who recorded comparable findings of seed bio-priming with *Rhizobium*, PSB, and KMB with 100% RDF of NPK, yielding the highest values across various plant growth parameters and grain yield, which were statistically similar with seed bio-priming using *Rhizobium*, PSB, and KMB with 75% RDF of NPK.

Table 2: Effect of different bioinoculants on nodulation and grain yield of chickpea

Treatment details	Number of nodules per plant	Nodule dry weight (mg/plant)	Plant dry weight (g/plant)	Grain yield (q/ha)
Uninoculated control (T ₁)	12.67	41.39	3.18	11.78
<i>Mesorhizobium</i> (AKCR1) (T ₂)	23.73	65.33	4.36	16.14
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> (T ₃)	23.87	69.86	4.45	16.59
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> + PSB (T ₄)	25.00	73.83	4.65	17.94
<i>Mesorhizobium</i> (AKCR-1) + <i>Pseudomonas</i> + PSB + KSB (T ₅)	26.20	75.92	4.81	19.65
T5 + 100% RDF (T ₆)	28.33	87.31	5.23	23.60
T5 + 75% RDF (T ₇)	28.20	85.02	5.04	22.31
T5 + 50% RDF (T ₈)	26.87	81.97	4.98	20.89
T5 + 25% RDF (T ₉)	26.40	78.51	4.94	19.87
F- test	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.42	0.80	0.19	0.89
CD @5%	1.27	2.40	0.58	2.67

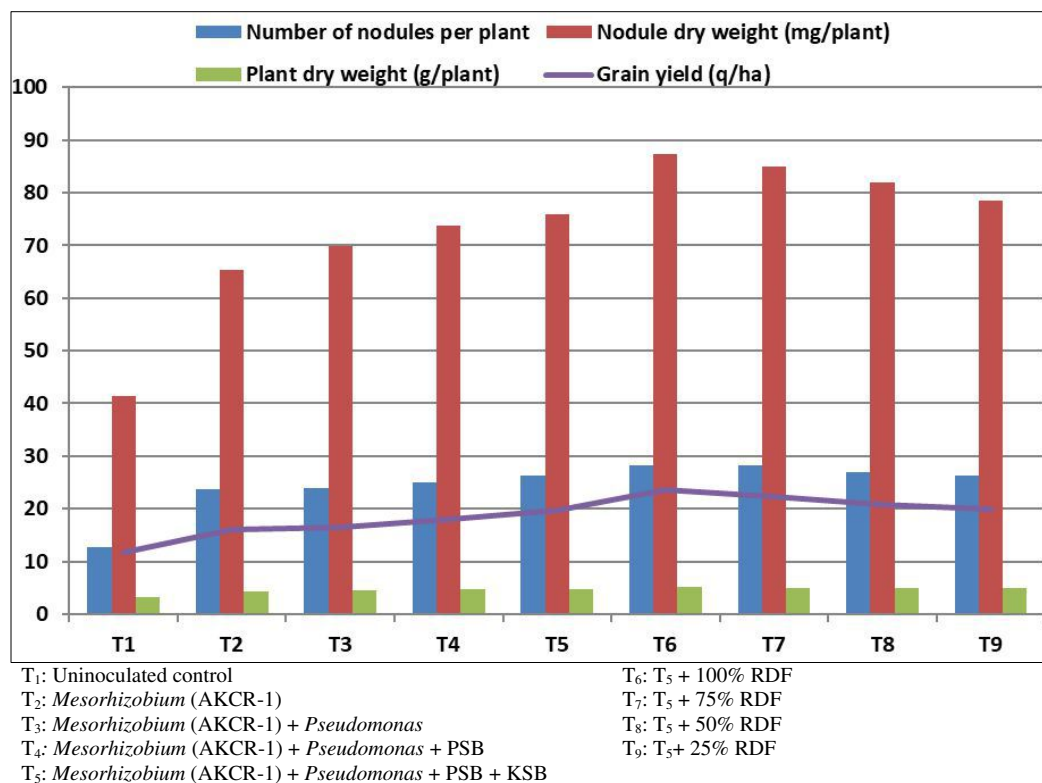


Fig 1: Effect of different bioinoculants on nodulation and yield of chickpea

4. Conclusion

The present study concluded that seed inoculation with different (biofertilizers) bioinoculants [*Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB and KSB] + 100% RDF recorded maximum nodulation, root and shoot length, plant height, plant dry weight and grain yield and it was statistically at par with the treatment of *Mesorhizobium* (AKCR-1) + *Pseudomonas* + PSB + KSB + 75% RDF. Hence the high dose of inorganic biofertilizers for the maximum production of chickpea can be reduced upto 25% and keep safe the environment.

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